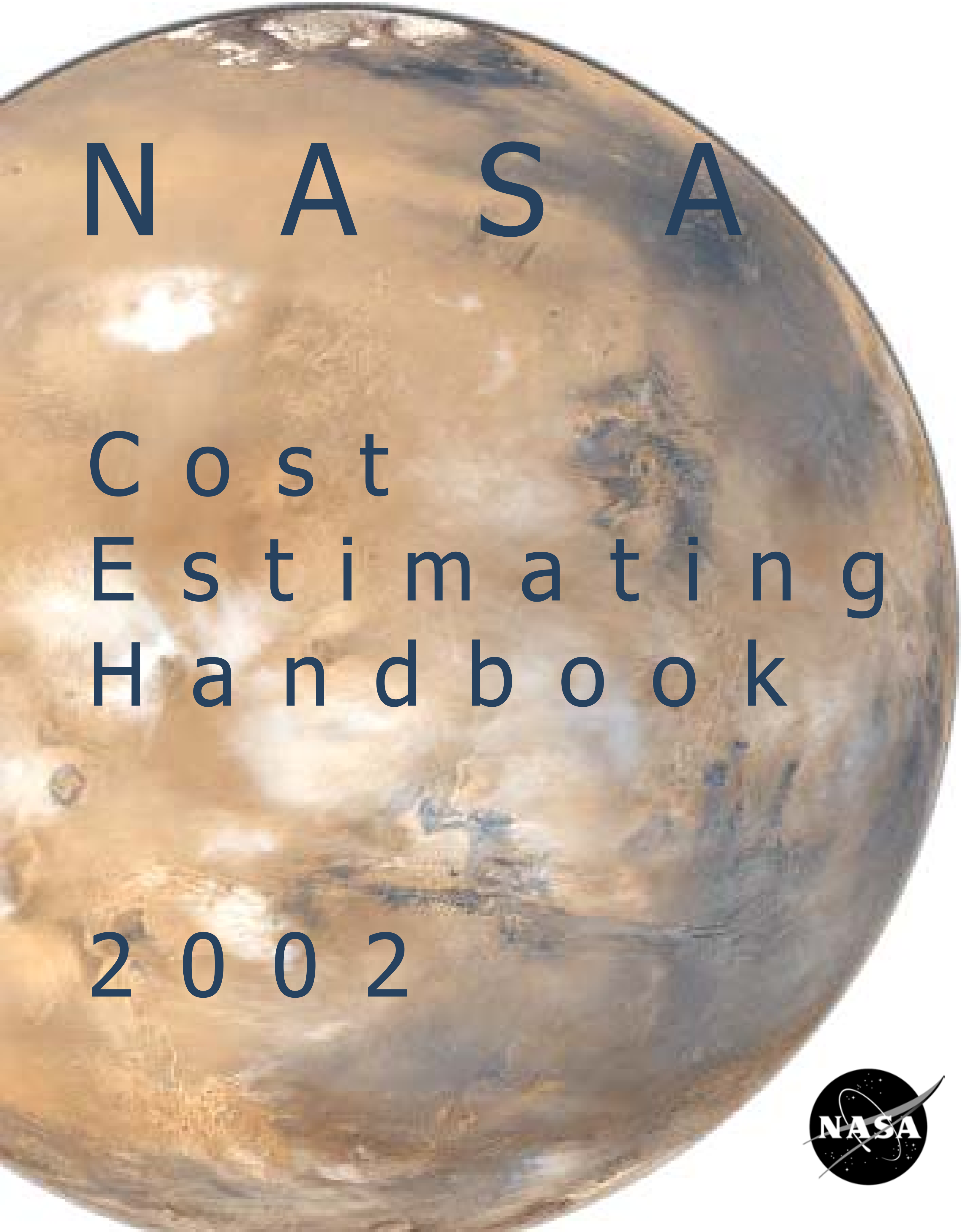

NASA

Cost Estimating Handbook

2002

National Aeronautics and Space Administration

NASA HQ
Washington DC

This is our first attempt to provide a working version of National Aeronautics and Space Administration's (NASA) Cost Estimating Handbook. It is provided as an educational tool written from a NASA perspective. It covers the fundamental concepts and techniques of cost estimating as applied in NASA. Your comments are strongly welcomed to improve this working version and develop it as the official NASA Cost Estimating Handbook.

Our Administrator recognizes the importance of cost estimating as a critical NASA competency to support the financial decision-making process in the life cycle of programs and projects. NASA's financial goal is to implement programs and projects in a responsible manner to the public who have entrusted us with their valuable resources.

Together, we are pursuing America's space program and you represent NASA's greatest strength. Providing this handbook demonstrates NASA's commitment to its people. By using this handbook in your day-to-day work, you will have an opportunity to participate in the fulfillment of our Agency's overall goals set forth in the President's Management Agenda and articulated in the NASA Strategic Plan.

Steve J. Isakowitz

NASA Comptroller

Spring 2002

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P r e f a c e

Of the major challenges facing NASA today, perhaps none is more difficult than the challenge of managing a world-class research and development agency for aeronautics, space science, and technology in an environment of constrained resources. To meet this challenge head on, NASA has embarked on several initiatives aimed at aligning its programs with unfolding budget realities. Foremost in these efforts has been the development of NASA's strategic plan and strategic planning process. To meet the strategic goals set forth in the President's Management Agenda (PMA), in the NASA Strategic Plan, and in the NASA Cost Analysis Improvement Plan, the NASA Cost Estimating Community (CEC) has responded by beginning new initiatives of its own, including this handbook.

The NASA Cost Estimating Handbook (CEH) is a collaborative document developed through hours of interviews, discussion, and correspondence with the NASA CEC. Interviews with the NASA CEC and Independent Program Assessment Office (IPAO) staff were held to research and document cost estimating best practices embraced by NASA, to garner a feel for the environments where NASA cost estimators perform their estimates, and to see, first hand, how the CEH can enhance the cost estimating capability. The CEH strikes a balance between documenting processes and providing basic resources for cost estimators from the beginner to the experienced, without setting a tone of strict guidance. It is supplemented by Center specific examples where appropriate.

The NASA CEH brings the fundamental concepts and techniques of cost estimating to NASA CEC personnel in a way that recognizes the nature of NASA systems and the NASA environment. This handbook is a top-level overview of cost estimating as a discipline, not an in-depth examination of each and every aspect of cost estimating. It is also a useful reference document, providing many pointers to other sources for details to complement and to enhance the information provided on these pages. In addition to the back to basics approach, the CEH has been created to facilitate increased credibility and communications within and beyond the NASA CEC by promoting the knowledge and skills necessary to formulate consistent and accurate estimates.

Accurate and defensible estimates are at the core of the future credibility of the NASA CEC. Regardless of whom the estimate is being prepared for, who the decision-maker is or to whom the estimate is being presented, the estimator must always remember that the ultimate customer is the cost-estimating discipline. Truth and accuracy combined with a defensible and well-documented estimate will always earn the respect of a decision-maker.

Cost estimation is part science, part art. There are many well-defined processes within the cost estimating discipline. There is also a subjective element to cost estimating that makes the discipline an art[1]. An attempt is made to capture the art form as well as the science in this text. The current perception that cost estimating is a "black box" can be demystified by accurate, defensible, well-documented estimates that are consistently presented and can be easily understood. This handbook is a starting point.

1 *We are not referring to the perceived "black box" of cost estimating but rather the art form that is learned over time and through experience.*

Both the NASA CEC as a cost estimating group and cost estimating as a discipline are undergoing rapid evolution. Over the next decade, many significant changes will no doubt occur, and many are already in progress. NASA's new Administrator (Mr. Sean O'Keefe) has made it clear that managing cost is important. New tools such as Cost Analysis Requirements Description (CARD) implementation and the level of review, validation, and verification that cost estimates will require are positive indicators of the future and growth of cost estimating at NASA.

This document is the "first ink" that will be refined over time and through use. This first edition is a living document developed to be a useful tool for the NASA Cost Estimator. Our mark of success is your feedback, dialogue, and a dog-eared copy of the NASA CEH on your desk.

Feedback, comments, suggestions, and/or corrections are welcomed. Please send your comments to the NASA IPAO point of contact, Mr. Rey Carpio at R.S.Carpio@larc.nasa.gov.

A c k n o w l e d g m e n t s

The material for this handbook was drawn from many different sources, including Center cost estimating procedures, NASA Performance Guides (NPGs), and industry best practices. To gather the most up-to-date information for this handbook, subject matter experts from NASA Centers were interviewed and we gratefully acknowledge their contribution to this document. Seven Centers were visited and 14 interviews were conducted with numerous participants. The NASA Cost Estimating Community Principal Contributors and Reviewers for this NASA CEH include:

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1 Overview

Welcome to the NASA Cost Estimating Handbook (CEH). This handbook has been designed to provide useful information on cost estimating for the entire NASA Cost Estimating Community (CEC). Its objective is to be informative for the new NASA cost estimator and a good reference for the experienced NASA cost estimator. It can be used to guide an estimate from start to finish or on an occasional basis as a reference. Data provided here have been selected because of their application to NASA cost estimators. Consequently, it provides NASA-relevant perspectives and NASA-particular data that are relevant to the NASA environment. The data provided in this handbook will facilitate the development of reliable cost estimates that are well documented, comprehensive, and defensible.

1.1 Purpose

The purpose of this handbook is to be a general reference document for the fundamental concepts and techniques used by the NASA CEC to prepare cost estimates. Standardizing costing methodologies and processes across NASA will provide consistency to the process and, thereby, increase the credibility of the resulting cost estimates. In this first version, the handbook takes a "back to basics" approach to help enhance cost estimating capability and increase communication among the estimating community and other NASA entities.

On a broad scale, the CEH along with other initiatives, will support increased project accountability to NASA leadership and can provide a higher "return" in the form of science, research and technology advancement in the development of space and aeronautics. The creation of a NASA CEH provides opportunities to improve cost estimating accuracy, consistency, and credibility by aligning each of the NASA Centers with a common process and vision for cost estimating.

1.2 Scope

Cost estimating is a very broad topic. The coverage in this handbook is limited to general concepts and generic descriptions of processes, techniques, and tools. The CEH provides information on solid cost estimating and analysis practices as well as caveats and areas to avoid. This handbook describes cost estimating as it should be applied to the development of major NASA programs and projects.

Since the missions of each of the NASA Centers are different, it is recognized that the cost estimating requirements and approaches will be different. Therefore, this handbook is not able to provide complete and exhaustive guidelines to all NASA cost estimating and analysis personnel for all situations. Each NASA cost estimating office may choose to supplement these general guidelines, as appropriate, with specific instructions, processes, and procedures that address each Center's unique situations and requirements. Furthermore, each cost estimator is expected to reach beyond the approaches and methodologies described in this handbook when they prove inadequate or whenever circumstances warrant. This is where art meets science in the field of cost estimating. Both NASA and the NASA CEC are undergoing rapid changes. Over the next few years many changes will occur. Some of these changes are already in progress, for example implementation of the Cost Analysis Requirements Description (CARD). These circumstances should be kept in mind when using this CEH.

1.3 Organization

This handbook is a quick reference guide that is easy to navigate. The intent is to give an overview of a topic that is easy to read and comprehend quickly and gives the user the summary of the topic and how it is used at NASA. References have also been included where appropriate to direct the reader to other sources for a more in-depth discussion of the topic. This document should only be considered a starting point.

The handbook consists of four core sections: cost estimating, financial analysis techniques, benefits analysis, and special studies/analysis. The first three appendices provide general information. Appendix A provides a complete list of acronyms used in this handbook. Appendix B provides a glossary of terms used in this handbook. Appendix C provides list of references. The remaining appendices contain supporting or related information to supplement these core sections.

2 Overarching Philosophy

This NASA CEH outlines a comprehensive and consistent program for cost estimating that supports the President's Management Agenda (PMA) as well as NASA specified goals. The PMA[2] identifies four government-wide and program initiatives that the NASA CEC can make changes that will have an impact. These initiatives are:

Competitive Sourcing – Detailed estimates of full cost government performance to the taxpayer are needed for identifying the most efficient means of accomplishing a task. *The NASA CEC can have an impact on this initiative by providing estimates to support studies, conducting trade studies for efficiency, and supporting full cost accounting.*

Improved Financial Performance – Erroneous payments and accounting errors reduce confidence in Government systems. Changes will be made in the budget process that will allow "better measure of the real cost and performance of programs." *The NASA CEC can have an impact on this initiative by providing timely and accurate cost estimates that serve as performance baselines and reconciling and updating the estimates frequently.*

Budget and Performance Integration – Improvements as discussed above will have little impact unless they are linked to better results. A budget comparison of procurement funds requested and identified need is not an accurate measure of performance results achieved with previous budgets. *Realistic and defensible cost estimates, integrated, incorporated, and reconciled to NASA budgets can have an impact on future requirements and demonstrating results.*

Better R&D Investment Criteria – NASA's goal of the space and science program, to "chart our destiny in the solar system" is considered too vague and leads to "perpetual programs achieving poor results." *The NASA CEC can have an impact on this initiative with estimates that accurately represent the life cycle cost of a program and trade studies that help make smart investment trades and decisions.*

The 2003 President's Budget for NASA includes five areas in the President's Proposal for NASA[3]. From these five areas, two are initiatives that the NASA CEC can directly affect. These proposed items are:

Cost Overruns	Getting the massive cost overruns in Human Space Flight (HSF) development programs under control while maintaining current programs. *The NASA CEC can directly affect this area by accurately baselining costs associated with the technical baseline, following a more traceable and defensible estimating process, and understanding the cost drivers and how to manage them.*
Reducing NASA's Operational Burdens	Pursuing Space Shuttle Competitive Sourcing, while furthering research goals for R&D. *The NASA CEC can have an impact on this goal by producing accurate performance, cost, and schedule estimates.*

As evidenced by this list, there are many areas of the highest priority to the U.S. President and to the NASA Administrator where cost is a major topic and where NASA's CEC can have an impact. Cost Estimating is an increasingly important discipline that can have direct influence on the future of NASA. NASA's CEC does not take this responsibility lightly.

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2 For more, see the President's Management Agenda at http://w3.access.gpo.gov/usbudget/fy2002/pdf/mgmt.pdf.

3 For more, see FY2003 Budget of the United States Government.

2.1 Why is Cost Estimating Important?

Cost estimating is important because of its direct impact on NASA and the United States. NASA, like other agencies, has received reduced funding to carry out its mission and programs. With recent cost overruns and attention being focused on NASA and other Government agencies, it is the responsibility of the NASA CEC to revamp and enhance the current cost estimating infrastructure. This transformation will provide greater information management support, more accurate and timely cost estimates, and more complete risk assessments that will increase the credibility of the NASA CEC and in turn NASA as an agency. The NASA CEC serves to provide decision-makers throughout NASA with accurate, reliable, and defensible cost estimates. These cost estimates are one of the best tools available to meet the stated objectives of three of NASA's four crosscutting processes goals[4] shown in Exhibit 2-1.

Crosscutting Processes Goals	Objectives
Manage Strategically: Enable the Agency to carry out its responsibilities effectively, efficiently, and safely through sound management decisions and practices	• Protect the safety of our people and facilities, and the health of our workforce, • *Enhance the security, efficiency, and support provided by our information technology resources,* • *Manage our fiscal and physical resources optimally,* • *Achieve the most productive application of Federal acquisition policies, and* • *Invest wisely in our use of human capital, developing and drawing upon the talents of all of our people*.
Provide Aerospace Products and Capabilities: Enable NASA's Strategic Enterprises and their Centers to deliver products and services to our customers more effectively and efficiently	• Enhance program safety and mission success in the delivery of products and operational services, • *Enable technology planning, development, and integration driven by Strategic Enterprise customer needs,* • Facilitate technology insertion and transfer, and utilize commercial partnerships in research and development to the maximize extent practicable, • Improve NASA's engineering capability, to remain as a premier engineering research and development organization, and • *Capture engineering and technological best practices and process knowledge to continuously improve NASA's program/project management*.
Generate Knowledge: Extend the boundaries of knowledge of science and engineering through high-quality research	• Improve the effectiveness with which we— – Acquire advice from diverse communities, – Plan and set research priorities, – *Select, fund, and conduct research programs, and* – *Analyze and archive data and publish results*.

Exhibit 2-1: NASA's CEC Supports NASA's Strategic Plan's Crosscutting Processes Goals

The NASA CEC can help decision-makers meet NASA's strategic goals. NASA generated cost estimates should be comprehensive, examining not only the costs associated with an investment but also the benefits (quantitative and qualitative). Qualitative benefits, which may be intangible, can have a direct link to an organization's strategic vision, mission, and performance. These benefits are captured in the full analysis provided with a cost estimate. This provides a Program Manager with a complete picture of the investment's potential impact.

4 For all of the crosscutting processes goals listed in the NASA Strategic Plan, see http://www.hq.nasa.gov/office/codes/plans/FlashPlan/INDEX.htm.

3 Roles & Responsibilities

This section describes NASA's cost estimating requirements, cost estimating organizations and their roles and responsibilities, and the types of estimates that the NASA CEC conducts.

3.1 NASA Requirements for Cost Estimates

Cost estimating and the development of accurate and defensible cost estimates for programs and projects at NASA are critical for good program and project planning and for the long-term success of NASA. NASA Program and Project Management Processes and Requirements, NASA Performance Guide (NPG) 7120.5, provides the framework for managing NASA programs and projects and contains procedure for cost estimating at NASA. NPG 7120.5 provides guidelines for two required types of cost estimates:

Advocacy Cost Estimates (ACEs) – ACEs are prepared by the project or program office as advocates for the program/project. These estimates are also known as Life Cycle Cost Estimates (LCCs).
Independent Cost Estimates (ICEs) – ICEs are prepared by independent review teams.

3.2 Purposes of Cost Estimates

There are different purposes for cost estimates performed at NASA. The processes for conducting these estimates are similar and the basic analytical techniques do not vary. However, it is important to understand and recognize the differences between the purposes of estimates, the customer or requesting organization, and the use and expected result of the estimate.

3.2.1 Life Cycle Cost (LCC) Estimates

An LCC estimate provides an exhaustive accounting of all resources necessary to develop, deploy or field, operate, maintain, and dispose of a system over its lifetime. The life cycle of a system or a program equals its total life, beginning with mission feasibility and extending through operation and disposal or conclusion of the system or program. The LCC estimate should be comprehensive and structured to identify all cost elements including development, deployment, operation and maintenance, and disposal costs. It includes total cost of ownership over the system life cycle, including all program feasibility; program definition; system definition; preliminary and final design; fabrication and integration; deployment; operations and disposal efforts. The projected LCC of a program should reflect both on the life span of the program and on program objectives, operational requirements, or contractual specifications.

LCC Estimate

How an LCC estimate is used

An LCC estimate is a critical component of the information needed to make decisions to implement proposed programs or projects or courses of action, and to evaluate the success of existing projects or courses of action. A program's LCC estimate should be used to affect the decision to proceed with the development or production of the system, based on total resources foregone by taxpayers, regardless of funding source or management control. It also helps decision-makers determine the appropriate scope or size of the program/project or course of action. Therefore, underestimating LCCs will prevent decision-makers from making correct decisions on the appropriate allocated funding required to support the program/project. On the other hand, overestimating LCCs may result in the program being deemed unaffordable and therefore risking not being funded.

3.2.1.1 Advocacy Cost Estimates (ACEs)

Cost estimators, as a member of the product or program design team, prepare ACEs. These LCC estimates are based on translating the technical and design parameter characteristics into cost estimates using established cost estimating methodologies. Iterative and on-going reviews are conducted with members of the technical team during the design process until the cost estimator and the program/project management team is confident that the cost estimate accurately reflects the baseline program/project in terms of design requirements, technical capabilities, management structure, and operational scenarios. The ACE then becomes the basis for the budget baseline for the program/project.

ACEs are prepared by the program/project office in support of:

1) **The development of the program commitment,**
2) **Major reviews, and**
3) **Budgetary submissions.**

Advocacy Cost Estimates

Formulation Phase Advocacy Cost Estimates (ACEs)

NASA cost estimators often support the program/project during the formulation phase with a parametric cost estimate that is compared with a grass-roots estimate or a contractor estimate. Although this type of estimate is "independent" in the sense that it is developed separately from the grass-roots estimate, it's not really an independent LCC estimate per NPG 7120.5 since the estimator is really functioning as an advocate for the program/project manager when providing this estimate. Hence, this is an advocacy estimate. Since these occur during the formulation or even pre-formulation phase in many cases, parametric cost estimating tools and techniques are typically employed to develop these estimates. These estimates may or may not include operations costs, so they might not always be traditional LCC estimates.

3.2.2 Independent Cost Estimates (ICEs)

ICEs are LCC estimates prepared as a result of an independent review of a program/project. The ICE is based on the same program definition including lifecycle, Work Breakdown Structure (WBS), and phase as defined in the Program LCC estimate (the ACE). However, this estimate, including the data sources and cost estimating approaches, is intentionally independent from the LCC estimate. The types, purpose, and frequency of these independent reviews are identified in NPG 7120.5. ICEs are developed by the cost estimators of the independent review team to provide program/project management with the review team's assessment of how realistic are the project's LCCs.

Independent Cost Estimates	Formulation Phase Independent Cost Estimates (ICEs)
	ICEs during the formulation phase support independent reviews of programs/projects per NPG 7120.5. Although the tools and techniques to develop the baseline ICE are similar to those employed for the ACE, the emphasis is different. The ICE is developed by an independent review team (as opposed to the program/project) and focuses on providing cost estimates as a result of questioning assumptions and identifying and quantifying technical and programmatic risks, risk mitigation strategies, and reserve strategies. The ICE from one of these reviews may result in a delta to the program's baseline estimate or a new estimate.

3.2.2.1 Non-Advocate Review (NAR)

The approval sub process for all programs and selected projects must include a NAR, which provides an independent verification of a candidate program/project's plans, LCC status, and readiness to proceed to the next phase of the program's life cycle. A NAR is conducted by a team comprised of highly knowledgeable specialists from organizations outside of the advocacy chain of the program/project being reviewed.

3.2.2.2 Independent Annual Review (IAR)

An IAR is conducted to validate conformance to the Program Commitment Agreement (PCA) and provides the status and performance of the program to the NASA Program Management Council (PMC). An IAR provides: an assessment of progress/milestone achievement against original baseline, a review and evaluation of the cost, schedule, and technical content of the program over its entire life cycle; an assessment of technical progress, risks remaining, and mitigation plans; and a determination if any program deficiencies exist which result in revised projections exceeding predetermined thresholds.

3.2.2.3 Independent Assessments (IA)

An IA is performed in support of the NASA PMC oversight of approved programs or projects. The IA is a validation of an advanced concept typically conducted in the formulation phase sub process. The IA is conducted by a team comprised of highly knowledgeable specialists from organizations outside of the advocacy chain of the program/project. The results of an IA provides the NASA PMC with an in-depth, independent validation of the advanced concepts, program/project's requirements, performance, design integrity, system/subsystem trades, LCC, realism of schedule, risks and risk mitigation approaches, and technology issues. The results of an IA also provide suggestions of alternative system and/or subsystem design approaches that offer potential for reduced costs and risks or improved system performance.

3.2.3 Cost Estimate Reconciliation

This reconciliation activity is not an estimate, but rather an exercise to synthesize and reconcile the cost estimates mentioned above, such as an ACE and an ICE. The estimates are examined for completeness and reviewed to get an understanding for the basis of each. During this process, similarities and differences are analyzed and problems of duplication or omission are resolved. Reconciliation of these estimates results in a formal cost estimate. A formal cost estimate supports a final commitment, approved by the appropriate level of Center management and is related to a specific and well-defined program/project.

3.2.4 Announcement of Opportunity (AO) Proposal Estimates

An AO is generally used to solicit proposals for unique, high-cost research investigation opportunities that typically involve flying experimental hardware provided by the bidder on one of NASA's Earth-orbiting or free-flying space flight missions. Selections through AOs can be for periods of many years, involve budgets of many millions of dollars for the largest programs, and usually are awarded through contracts, even for non-profit organizations, although occasionally grants are also used. An estimate supporting an AO is a proposal estimate. Many Centers have developed proposal tools and templates to help expedite the estimate for these quick turnaround efforts. Much of the data to support these estimates is supplied by the contractor.

3.2.5 Budget Support Estimates

The assessment tools and skills used to conduct a budget support estimate are different than those used in a traditional LCC estimate and are not addressed in this CEH. Methods and tools used in budget support estimates may vary among Centers. Many times, ICEs conducted during the implementation phase of a program are more independent budget assessments that actually use very little cost estimating tools and techniques. These estimates rely instead on traditional resource and budget analysis techniques and many times are not conducted by a cost estimator, but rather a resource analyst.

For example

For example, the independent review team relates the technical content to the schedule and budget by reviewing the Program Operating Plan (POP) and other budget data, earned value assessments, spend rates, cost and obligation history, programmatic and technical threats and liens, costed vs. uncosted actuals, year-end carry-over amounts, anticipated budget cutbacks and fallback plans, deferred technical content, and associated budget impacts. The team reviews all of these elements in terms of program's performance to-date, as well as the assumptions made by the program for its future performance. The independent review team then converts their assessment of these programmatic elements into estimates at completion (EAC) to estimate the LCCs.

Exhibit 3-1 gives an overview of the performance and budgeting planning implementation process at NASA.

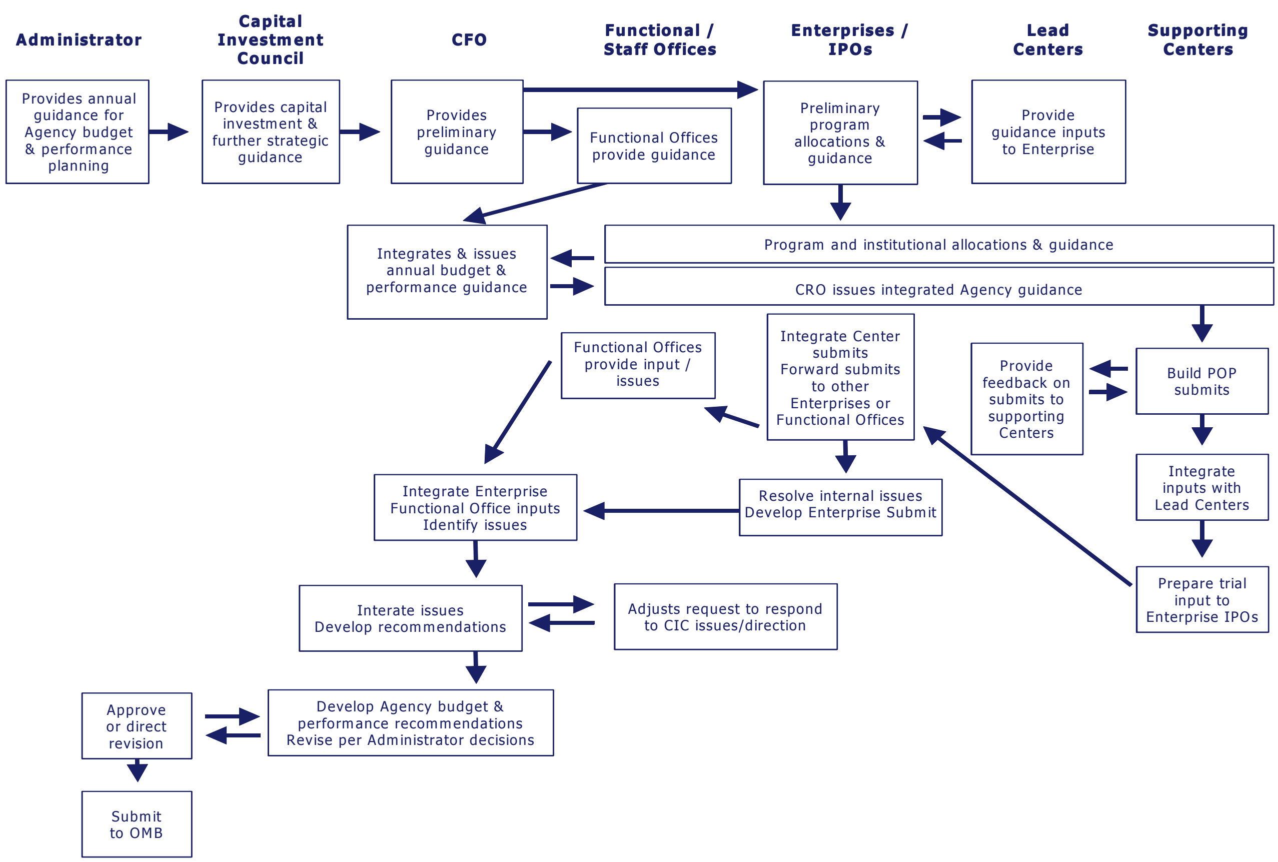

Exhibit 3-1: Implementation: NASA's Performance and Budgeting Planning[5]

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5 *From NASA Strategic Management Handbook.*

3.2.5.1 Earned Value Management (EVM) Techniques and Formulating an Estimate at Completion (EAC)

The assessment tools and skills used to conduct this type of estimate are different than a traditional LCC estimate and are not addressed in this CEH. EVM is a recognized management tool that ties cost, schedule, and technical performance together. Using fairly standard analysis techniques, actual performance data from a project can be used to estimate the final cost of the project, an EAC. For example, the analyst(s) relates the technical content to the time-phased, resource-loaded budget baseline. The analysts may also look at programmatic and technical risks, threats, liens, and deferred technical content with associated budget impacts. The analyst reviews all of these elements in terms of performance to date, as well as the assumptions made by the program for its future performance.

3.3 NASA Organizations Involved in Cost Estimating

A brief description of the functions of each of the overarching NASA offices and organizations involved in cost estimating activities follows. Organizational charts depicting the organizational structures of the cost estimating function within each NASA Center is presented in Appendix D.

Agency CFO	**Agency Chief Financial Officer (CFO).** The NASA CFO at Headquarters (Code B) is responsible for: • Developing overall agency policies, guidelines, and procedures for budget administration, financial reporting, and financial management systems; • Formulating policies governing how financial services are provided and managed; • Establishing and maintaining accounting principles, procedures, and systems; • Developing policies and standards for cash and credit management; and • Maintaining liaisons with the Office of Management and Budget (OMB), the Department of Treasury, the General Accounting Office (GAO), and various Congressional committees with Agency financial management oversight activities.

NASA CFO Council	The **NASA CFO Council** assists the NASA CFO in the performance of these responsibilities. The CFO Council includes key Agency financial and resources management officials and has been established to strengthen coordination and communication regarding all financial and resources (budget) management matters.[6]

[6] *NASA Office of the Chief Financial Officer, 2/13/02, http://ifmp.nasa.gov/codeb/about/about.htm*

IPAO

Independent Program Assessment Office (IPAO). The IPAO is a Headquarters office located at LaRC. The IPAO's role in cost estimating is to provide leadership and strategic planning for the cost estimation core competency by:

- Interfacing with the Agency CFO and the Office of the Chief Engineer (Code AE) at NASA Headquarters regarding cost analysis requirements and processes,
- Providing instruction on cost tool use,
- Developing specialized cost tools,
- Ensuring consistent, high-quality estimates across the Agency,
- Fostering a "pipeline" of competent NASA cost analysts,
- Providing independent, non-advocate cost estimates and cost-benefit analyses, and
- Chairing the Cost Estimating Working Group and the annual NASA Cost Symposium Workshop.

CEWG

Cost Estimating Working Group (CEWG). The purpose of the CEWG is to strengthen NASA's cost estimating standards and practices by focusing improving tools, processes, and resources (e.g., training, employee development). Membership is comprised of senior cost estimating analysts from each NASA Center. The working group is also a forum to foster cooperation and interchange in areas such as sharing models and data across Centers and implementing "lessons learned". The CEWG meets three times a year at different NASA locations. The IPAO serves as the Chair of the CEWG. The CEWG also sponsors the annual NASA Cost Symposium Workshop which provides an opportunity for all NASA cost estimators, including support contractors, to present technical briefs on topics such as the status of cost model development, case studies, lessons learned, and other cost analysis research areas. A recent Point of Contact (POC) list for the CEWG is located in Appendix E.

CAOs

Cost Analysis Offices (CAOs). The CAOs at each NASA Center provide analysis, independent evaluations, and assessments of Center programs and projects, including programs delegated to the Center as lead Center. Organizationally, many of the CAOs are located in the System Management Office (SMO). Some CAOs are intrinsically tied into technically oriented technology assessment at component, sub-system, system and architecture levels to perform cost and project assessments. Other CAOs are located under the Center's CFO, Resource Management Office (RMO), or Business Management Office (BMO). Although the functions and responsibilities of the CAOs may vary slightly from Center to Center due to differences in the mission and organizational structure, their role is generally to:

- Serve as the Center's focal point for independent cost estimating and analysis for programs and projects,
- Support NARs, IARs, and IAs of Center programs and projects,
- Ensure that programs and projects develop and implement management practices, policies, processes, and procedures that are consistent with the NPG 7120.5, *NASA Program and Project Management Processes and Requirements*,
- Promote the use of advanced project management analytical tools and processes for improving cost, LCC, and schedule estimating and analysis capabilities,
- Maintain contacts with the cost estimating offices at other NASA Centers (through the CEWG and other forums) to coordinate and promote consistent cost and schedule functions, processes, approaches, and analyses across all NASA Centers, and
- Provide cost analysis expertise to the IPAO to support independent reviews as requested.

3.3.1 Cost Estimating Community at the NASA Centers

The CEC at NASA is an increasingly cohesive group and this handbook serves as a teaching and communication device among the Centers and the community. As the NASA CEC becomes more cohesive, it cannot be forgotten that each Center's cost estimating capability is unique, by mission support, culture, and functionality. As evidenced by Exhibit 3-2, the NASA CEC falls into a different functional organization at each Center. Depending on the focus and the culture at the Center, the cost estimators are aligned with the most logical organization for the Center to efficiently access their cost estimating capability.

NASA Centers	SMO/Chief Engineer	CFO	Center Operations
NASA Headquarters			
LaRC IPAO	X		
ARC		X	
DFRC			
GRC		X	
GSFC	X		
JPL	X		
JSC	X		
KSC	X		
MSFC	X		
SSC			X

Exhibit 3-2: NASA CEC Falls into a Different Functional Organization at Each Center

4 Cost Estimating

4.1 Foundation of the Cost Estimate

As discussed in the previous section, cost estimates serve different purposes. Each estimate has a different customer and a slightly different focus, which are important to recognize when beginning an estimate. However, the estimating process itself does not vary greatly between the different types of estimates. This section describes the basics of the cost estimating process at NASA.

It is important to build a solid foundation before the estimate process is initiated. There are four critical elements to any estimate that need to be understood and agreed upon between the cost estimator and the decision-maker before a methodology can be chosen and an estimate can be developed. As shown in Exhibit 4-1, the four elements are resources, data, schedule and expectations. An estimator conducting any estimate, from the back of an envelope to a formal estimate, should consider these factors before choosing a methodology to conduct the estimate.

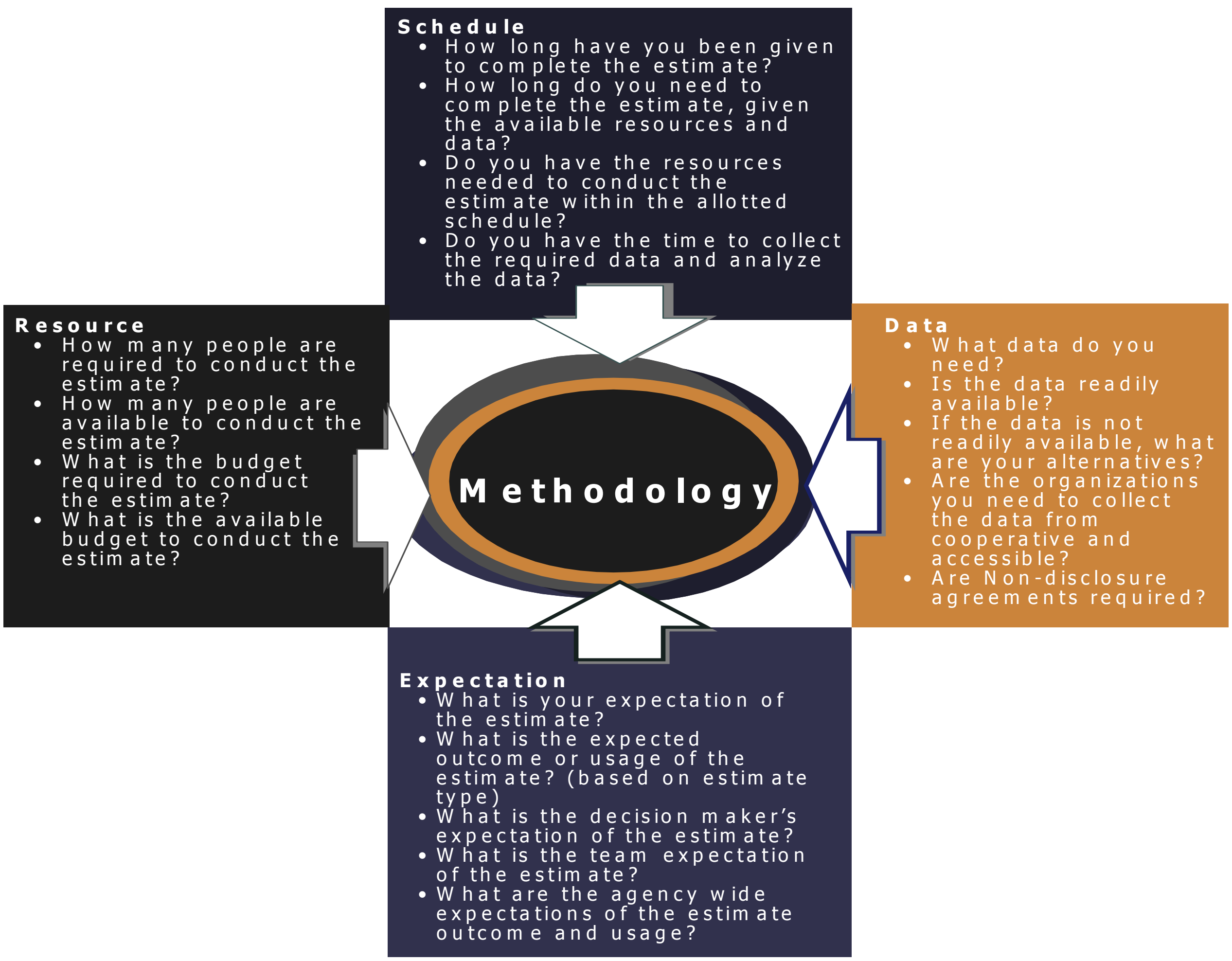

Exhibit 4-1: Four Elements to Selecting a Cost Estimating Methodology

All of these factors directly affect the overall methodology selected for conducting the estimate. Various methodologies and rules of thumb for most effective usage are described in this section.

4.2 Cost Estimating Process at NASA

With any process, it is easy to fall into the trap of following each step in serial, without taking into account other critical factors or influences. These factors may require the process to become iterative. Exhibit 4-2 depicts a generic step-by-step process for developing a cost estimate, of which each step is described in detail in this section. Note that the process is depicted as a wheel, to demonstrate that the entire process itself is continuous. Certain steps within the process are iterative, not linear or serial, for example, data collection may occur at various steps within the overall process.

Exhibit 4-2: NASA Cost Estimating Process Overview

As a discipline, cost estimating is important to NASA's strategic achievement. Appendix F provides the NASA Cost Analysis Improvement Plan, which outlines goals and objectives for improving cost estimating in the NASA CEC.

4.2.1 Receive Customer Request/Understand the Program

When a request for a cost estimate is received from a program, project, directorate, or office, the supervisor of the CAO must ascertain if he/she has the resources to accept the assignment based upon his/her understanding of the expectations of the estimate. The estimator then determines the magnitude of the workload required, i.e., the type of estimate, the due date(s), and relative priority of the request. If the request is accepted, the supervisor will notify the requester of this fact and will assign an estimator (or estimators) to the task.

The first step for the estimator assigned to conduct a cost estimate is to understand the program/project. To calculate the relevant costs and associated benefits with respect to the assignment, it is important to understand the current processes and operating environment. Almost every mission and investment, whether in facilities, personnel, technology, or knowledge, affects numerous parts of the organization. It is the evaluation of the project's mission needs and objectives, and the assessment of the operating environment for the program that identifies which organization(s) or process(es) will be affected. The assessment of the baseline program environment also identifies the mission need, risks, and system deficiencies that have prompted the need for an estimate. Finally, the initial assessment establishes the baseline to which the estimate is compared.

4.2.2 Define Work Breakdown Structure

Regardless of the type of estimate, a consistent WBS is important to the estimate structure, to capture all costs, to communicate among review authorities and stakeholders, and to ensure compatibility with future estimates. Some WBS examples are listed in Appendix G. If a Cost Analysis Requirements Description (CARD) (See Section 4.2.3) does not exist for a program, or an estimate has never been conducted for the program, then a WBS may need to be created. If a CARD exists or an estimate has been conducted before, the WBS should be reviewed for accuracy, completeness, and any needed changes. A WBS has a strong product focus, generally including hardware and supporting services. There is no direct program life cycle orientation. The Development and Fabrication phases of a system are often addressed by seemingly duplicated elements, however element titles and definitions may be modified as appropriate, for example; development training, initial training, and recurring training. It is important to understand the entire program and the WBS to make sure all cost elements are captured. An unmodified WBS may result in a cost estimate that has gaps in coverage. For example the WBS is not designed to accommodate reserves for risk.

Tips

W B S T i p s

- MIL STD 881B (http://www.kolacki.com/MIL-HDBK-881.htm) can be referenced for more details on building a WBS.
- The OSD CAIG (http://www.dtic.mil/pae/paeosg04.html) provides guidelines for the development and definition of standard elements for O&M cost estimates.
- A WBS can also be called a cost element structure (CES).
- The WBS you create may not necessarily map to the estimating structures found in commercial tools used in the estimating community. Know the tool you plan to use before you begin.
- A "contract" WBS is based on the structure of the contract where the work is being performed. A "Program" WBS is an all-inclusive WBS that takes into account the additional programmatic elements.

4.2.3 Prepare or Obtain Cost Analysis Requirements Description (CARD)

Any NASA organization sponsoring a program/project will prepare, as a basis for life-cycle cost estimates, a description of features pertinent to costing the system being developed and acquired, known as the CARD. The CARD provides a system technical description and programmatic information to create a common baseline used by the project team to develop their estimates. The CARD is intended to have enough detail to enable an estimate to support an ICE; therefore no cost information or costing methods are included. The CARD should also assist with identification of any area or issue that could have a major cost impact and, therefore, must be addressed by the cost estimator. It is also intended to be flexible enough to accommodate the use of various estimation methodologies. The CARD defines, and provides quantitative and qualitative descriptions of, the program characteristics from which cost estimates will be derived. As such, the CARD ensures that cost projections developed by the Program/Project Offices and the independent review organizations are based on a common definition of the system and program.

W h e n i s a C A R D r e q u i r e d ?

No dollar value has been assigned as to when a CARD is required. The threshold for NASA CFO certification of an ICE is over $150m for programs moving from Phase A to Phase B. So, if an ICE is required, a CARD is required; however, programs less than $150m that require an ICE outside of the Congressional statutory CFO certification of Phase A to B also require a CARD. So the answer is "it depends."

What should a CARD include?

- Global and detailed ground rules and assumptions,
- Relationship mapping of specific Contract WBSs to the Program WBS,
- Quantities for spares/parts development and procurement,
- Where available, names of prime contractors and subcontractors/vendors that will be developing and producing subsystems or spares/parts should be identified,
- Support and training equipment, and if available Program WBS dictionary,
- Draft cost structure for all phases of the system life cycle (including the program WBS breakout and other categories such as facilities, construction, flight test site costs, O&S, etc.),
- Items should be identified as developed, refurbished, Commercial-Off-The-Shelf (COTS), or a Non-Developmental Item (NDI),
- Contracted and projected reliability and maintainability parameters at the respective repair/maintenance level for the system, and
- Descriptions of all effort associated with the program, regardless of fund source or management control must be presented in the CARD and should include responsibilities of each funding source.

A CARD should not include:

Costs or costing methods

The format of the CARD can vary, however it typically contains a project description, WBS, project ground rules and assumptions, project schedule, cost summaries for each of the WBS elements, and cost phasing summaries. Exhibit 4-3 demonstrates a CARD sample table of contents.

1.0 **System Overview**
- 1.1 System Characterization
- 1.2 Technical Characteristics
- 1.3 System Quality Factors
- 1.4 Embedded Security
- 1.5 Predecessor and/or Reference System

2.0 Risk

3.0 **System Operational Concept**
- 3.1 Organizational Structure
- 3.2 Basing and Deployment Description
- 3.3 Security
- 3.4 Logistics

4.0 Quality Requirements

5.0 System Manpower Requirements

6.0 System Activity Rates

7.0 System Milestone Schedule

8.0 Acquisition Plan and/or Strategy

9.0 **System Development Plan**
- 9.1 Development Phases
- 9.2 Development Test and Evaluation
- 9.3 Operational Test and Evaluation

10.0 Facilities Requirements

11.0 Track to Prior CARD

12.0 Contractor Cost Data Reporting Plan

Exhibit 4-3: Sample CARD Table of Contents

A well-constructed CARD helps reduce misunderstanding as to program content and significantly reduces time to reconcile estimates. The Program Office is responsible for ensuring the CARD is updated to reflect all program changes and the program cost team should be notified of all CARD updates. During the cost teams' review of the CARD, it is appropriate for cost teams to direct written queries to the Program Office's technical staff. The CARD should be as complete as possible but there will be unknowns so assumptions should be made and socialized with the Program Office to try to create an inclusive view of the program.

If several alternatives can meaningfully be described in a single CARD, then only one CARD need be submitted. For reviews, it is common for the Program Office and the independent cost team to develop complete LCC estimates for each alternative instead of relying on a more generic estimate. Providing separate estimates for each alternative is very useful when there are wide technical or physical differences among alternatives. When appropriate, CARDs for alternatives can be prepared as excursions to the preferred alternative. The level of detail of information in a CARD will vary depending on the maturity of a program. Programs at the Pre-formulation and formulation phases are less well defined than programs at the implementation phase. Ranges are common at pre-formulation, less so at formulation, and rare at implementation. Accurate and sufficient detail is critical to the usefulness of the CARD. Input options based on the quality of data available to the CARD preparers are identified in Exhibit 4-4.

Condition of Data	CARD Input
1. The required data are available.	Provide the data in the appropriate section of the CARD.
2. The data are contained in another document.	Summarize the data pertinent to cost in the appropriate section of the CARD and provide reference to the more detailed source.
3. There are no significant cost implications associated with that CARD section.	The CARD section should be identified as not relevant (N/R).
4. Sufficiently detailed definition is not yet available.	The available data should be provided and the remainder of the information should be identified as to be determined (TBD).
5. Uncertainty is associated with this area.	A range of values can be specified as opposed to a discrete value. If a range is used, it should be associated with a base case. Include rational for the range as well as a discussion of the significance of its variation for other parts of the system. If possible, designate a most likely or design value. As a program evolves and matures, it is anticipated that additional data, which will resolve TBDs and uncertainties, will become available and will be incorporated into the CARD.

Exhibit 4-4: Data Input Options Available to CARD Preparers

For more information

For more information please reference the DoD CARD guidance in 5000.4-M at http://www.hanscom.af.mil/ESC-BP/pollprev/docs/50004m.pdf. While 5000.4-M is not entirely applicable to NASA, it serves as a starting point and can be tailored to meet NASA requirements and the particular estimating environment. A more detailed guidance for developing and updating a CARD is included in Appendix H. DoD Instruction 5000.4-M, Chapter 1, also provides specific guidance for preparing and updating a CARD.

The Program Office is typically responsible for developing a CARD with sufficient depth and breadth for the ACE and the ICE. The measure of success and validation is the reconciliation effort of the two estimates. Accuracy is important. If the CARD details or assumptions are wrong, then all estimates will be flawed and reconciliation will be difficult.

The proper documentation of results is an important step in any analysis, especially parametric cost estimating. The purpose of the CARD is to provide a standard format for documentation. There are many reasons why good documentation is important in a cost estimate, and listed below are a few examples:

- Experience from formal cost reviews, such as NARs conducted by Code B, indicates that poorly documented analyses do not fare well in these reviews. The credibility of the total project suffers if the analyst is unable to explain the rationale used to derive each of the cost estimates. Conversely, if a reviewer understands your inputs, approach, and assumptions, your estimate remains credible in his/her eyes even if the reviewer disagrees with some aspect of it and recommends an adjustment.
- If the basis of the estimate is explicitly documented, it is easier to update the estimate and provide a verifiable trace to a new cost baseline as key assumptions change during the course of the project lifetime. This is especially important with respect to supporting the requirement imposed by NPG 7120.4 (http://nodis3.gsfc.nasa.gov/library/displayDir.cfm?Internal_ID=N_PD_7120_004B_&page_name=main&search_term=7120) to revalidate the Program Cost Commitment (PCC) annually. A well-documented CARD not only facilitates the establishment of the baseline PCC, but also aids the revalidation process and the development of updated PCCs.

4.2.4 Develop Ground Rules and Assumptions (GR&A)

Ground Rules and Assumptions (GR&A) are a critical step in any estimate and should be clearly prominent in all documentation and presentation material that the estimator prepares. A comprehensive list of the GR&A is a major element of a cost estimate. GR&A are important to define the program clearly and for estimators to be able to understand what costs are being included and excluded for the current estimate and future comparisons. By spending time developing and socializing accurate GR&A, problems can be avoided that may cause an inaccurate or misleading estimate.

The cost estimator works with the NASA Program/Project Manager and members of the technical team to establish and document a set of programmatic GR&A that are necessary to provide definition to the project and the estimate and to bound its scope. Each estimate should have two sets of GR&A, global and element specific. Global GR&A apply to the entire estimate and include ground rules such as base year dollars and total quantities. Element specific GR&A are found in the detail section for each WBS element. Detail GR&A provide specific details for each element such as unit quantities and schedules. Since it is impossible to know every technical or programmatic parameter with certainty in the design phase of a program/project, a complete set of realistic and well-documented GR&A adds to the soundness of a cost estimate. These GR&A should be developed in coordination with and agreed upon by the NASA Program/Project Manager.

For example

Below is a list of sample questions and subject areas that will be covered by an estimator preparing the GR&A.

- Guidance on how to interpret the estimate properly.
- Clarification to the limit and scope in relation to acquisition milestones.
- What base year dollars the cost results are expressed in, e.g., FY94$.
- Inflation indices used.
- Percentages (or approach) used for computing program level wraps: i.e., fee reserves, program support, OCD, Phase B Advance Development, PMS/IMS/ROS, HQ taxes, Level II Program Office.
- Production unit quantities, including assumptions regarding spares.
- Quantity of development units, prototype or prototype units.
- LCC considerations: mission lifetimes, hardware replacement assumptions, launch rates, number of flights per year.
- Schedule information: development and production start and stop dates, Phase B Authorization to Proceed (ATP), Phase C/D ATP, first flight, Initial Operating Capability (IOC) timeframe for LCC computations, etc.
- Use of existing facilities, modifications to existing facilities, and new facility requirements.
- Cost sharing or joint funding arrangements with other government agencies, if any.
- Management concepts, especially if cost credit is taken for charge in management culture, New Ways of Doing Business (NWODB), in-house versus contract, etc.
- Operations concept (e.g., launch vehicle used, location of Mission Control Center [MCC], use of Tracking and Data Relay Satellite System [TDRSS], Deep Space Network [DSN], or other communication systems, etc.).
- Operations and Maintenance period.
- Commonality or design inheritance assumptions.
- Specific items or costs excluded from the cost estimate.

GR&A are based on the operation, maintenance and support of the system. Descriptions of relevant missions and system characteristics, manning, maintenance, support, and logistics policies are generally included in the GR&A. All GR&A should be clearly stated and well documented. GR&A are more prominent in less defined formulation phase programs, because there are more unknowns and are less prominent in well defined implementation phase programs because there are less unknowns about the program. Global and detailed GR&A can also be found in the CARD.

4.2.5 Select Cost Estimating Methodologies

After the cost estimate requirements (resources, data, schedule and expectations) have been documented and understood, after the WBS has been developed, and after the GR&A have been defined and agreed to, the next most important step to be taken by a cost estimator is the selection of the most appropriate costing methodology or approach for the program/project.

Before initiating an estimate, the methodology for the estimate must be determined. This methodology will depend upon the type of system being estimated and the data available. Again, there are four key elements to be considered—when is the estimate due (schedule), how many estimators are assigned (resources), how much information is available (data), and what exactly does the customer want (expectations).

Cost estimating methodologies selected will also vary depending on the phase of the program. As shown in Exhibit 4-5, some methodologies are more appropriate during different program phases.

	Formulation Phase →		Implementation Phase	
	Pre-Phase A & Phase A	Phase B	Phase C	Phase D
Parametric	●	◕	◑	◑
Engineering Buildup	◑	◕	●	●
Analogy	◑	◕	◑	◑
● Primary	◕ Secondary	◑ Applicable	◔ Occasionally Used	○ Not Applicable

Exhibit 4-5: Selecting a Cost Estimating Methodology is Influenced by Program Phase

Proper selection of a methodology depends on the scope of the effort to be estimated, the detail of technical definition, the availability of usable historical costs, the maturity of the program, and the experience and skill level of the estimators. Most estimates are accomplished using a combination of the following four generally accepted estimating methodological approaches:

- Parametric
- Engineering build up
- Analogous system
- Vendor quotes/Rough Order of Magnitude (ROM)

As the program progresses from mission feasibility to deployment, more detailed information becomes available. Initial estimates are then updated as more data becomes available as the mission matures. Regardless of the estimating technique applied, appropriate documentation must accompany the estimate. A summary of each of these estimating techniques is presented in this section.

4.2.5.1 Parametric Estimating

Parametric estimates are most often used when there are only a few key pieces of data that are known. Many times this data relates to weight characteristics and design complexity. Parametric estimates are based on historical data and mathematical expressions relating cost as the dependent variable to selected, independent, cost-driving variables through regression analysis. The implicit assumption of this approach is that the same forces that affected cost in the past will affect cost in the future.

There are two types of parametric estimating, creating your own Cost Estimating Relationships (CERs) and using COTS or generally accepted (or NASA-developed) equations/models. For example, if using the NASA/Air Force Cost Model (NAFCOM) database, the estimator selects the inputs and NAFCOM will calculate the linear regression for you. Using a COTS package, such as PRICE (see Appendix I) or Galorath Incorporated SEER (see Appendix J) for parametric estimating gives the estimator two options. These models can be used as estimating environments to generate the entire estimate or as an estimating tool that gives the estimator the ability to generate a point estimate to be used as a throughput to another model. The major advantage of using a parametric model is that the estimate can usually be conducted quickly and is easily replicated.

Techniques to guide you in developing your own CERs are included in the following section.

4.2.5.1.1 <u>Using Regression Analysis to Derive a CER</u>

Exhibit 4-6 illustrates a method for developing a CER. A CER is an equation that relates one or more characteristics of an item to some element of its cost. A regression analysis is performed in anticipation of how costs will behave in relation to the inputs. For example, a study of an existing class of avionics equipment may yield a CER relating avionics unit cost to the weight of the avionics system. This CER could then be used to predict avionics unit cost for a new system whose weight can be estimated. A CER can also be used to relate to a different class of equipment, such as air versus space or communications versus data processing. Parametric estimating is normally used early in a system's life cycle when item specific data is not known. CERs must be examined to ensure they are current and that the input range of data being estimated is applicable to the system. All CERs should be well documented and explained. If they are improperly applied, the result could be a serious estimating error. Excel or other commercially available modeling tools are most often used for these calculations.

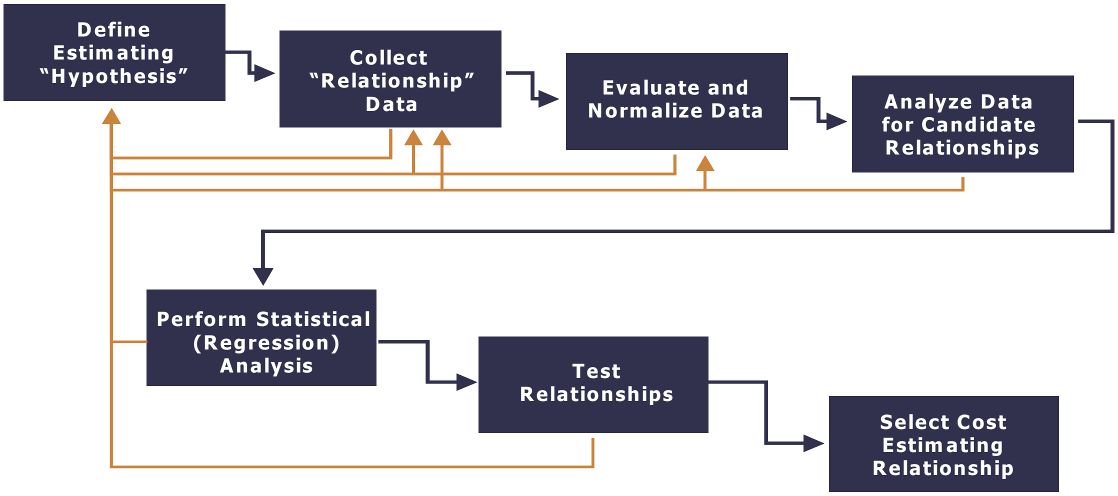

Exhibit 4-6: Developing a Regression Analysis

Exhibit 4-7 provides a list of the strengths and weaknesses of using parametric/CER method to develop a cost estimate.

Strengths	Weaknesses
Once developed, CERs are an excellent tool to answer many "what if" questions rapidly.	Often difficult for others to understand.
Statistically sound predictors providing information about the confidence of their predictive ability.	Must fully describe and document selection of raw data, adjustments to data, development of equations, statistical findings and conclusions for validation and acceptance.
Eliminates reliance on opinion (i.e., uses actual observations).	Collecting appropriate data and generating statistically correct CERs is typically difficult, time consuming, and expensive.
Defensibility rests on logical correlation, thorough and disciplined research, defensible data, and "scientific method."	Loses predictive ability/credibility outside its relevant data range.

Exhibit 4-7: Strengths and Weaknesses of Parametric/CER Method of Cost Estimating

To perform the regression analysis, the first step is to determine the relationship between the dependent and independent variables. Then, the data is fit using techniques such as:

- Linear regression: involves transforming the dependent and independent variables into linear forms
- Nonlinear regression: for data that is not intrinsically linear

What is the methodology

Regression Analysis Methodology

- Review the literature and develop the theoretical model.
- Specify the model.
- Select the independent variables(s) and the functional form.
- Hypothesize the expected signs of the coefficients.
- Collect the data.
- Estimate and evaluate the equation
- Document the results

With the addition of possible explanatory variables (see Exhibit 4-8), a more precise and robust regression equation can be obtained. Since more than one independent variable is likely to have an effect on the dependent variable, one can calculate multivariate regression:

Regression Coefficient	Meaning
β_1	Impact of a one-unit increase in X_1 on the dependent variable Y, holding constant all the other included independent variables (X_2 and X_3)
β_2	Impact of a one-unit increase in X_2 on Y, holding X_1 and X_3 constant
β_3	Impact of a one-unit increase in X_3 on Y, holding X_1 and X_2 constant

Exhibit 4-8: Regression Coefficient Meanings

4.2.5.1.1.1 Evaluating Regression Analysis Results

The most popular method of regression coefficient estimation is with a technique called Ordinary Least Squares (OLS). Many computer programs are capable of calculating estimated coefficients with OLS. Exhibit 4-9 provides a reference guide to help evaluate regression results.

Symbol	Checkpoint	Reference	Decision
X, Y	Data Observations	Check for errors, especially outliers in the data.	Correct any errors. If the quality of the data is poor, may want to avoid regression analysis or use just OLS.
$\hat{\beta}$	Estimated Coefficient	Compare signs and magnitudes to expected values.	If they are unexpected, respecify the model if appropriate or assess other statistics for possible correct procedures.
e_i	Residual	Check for transcription errors.	Take appropriate corrective action.
R^2	Coefficient of Determination	Measures the degree of overall fit of the model to the data.	A guide to the overall fit.
$\check{R}^2$	R^2 adjusted for degrees of freedom	Same as R^2. Also attempts to show the contribution of an additional explanatory variable.	One indication that an explanatory variable is irrelevant is if the $\check{R}^2$ falls when it is added.
TSS	Total Sum of Squares	TSS= $\sum (Y_i - \text{avg}Y)^2$	Used to compute R^2 and $\check{R}^2$
RSS	Residual Sum of Squares	RSS= $\sum (Y_i - \hat{Y}_i)^2$	Used to compute R^2 and $\check{R}^2$

Exhibit 4-9: Regression Analysis Reference Guide

Caveats & Limitations

Regression Analysis

Regression analysis is used not to confirm causality, as many believe, but rather to test the strength and direction of the quantitative relationships involved. In other words, no matter the statistic significance of a regression result, causality cannot be proven. Instead, regression analysis is used to test whether a significant quantitative relationship exists.

For more information

Regression Analysis Resources

- California State University, Long Beach (Regression)
  http://www.csulb.edu/~msaintg/ppa696/696regs.htm#REGRESSION
- London School of Economics and Political Science (Regression)
  http://econ.lse.ac.uk/ie/iecourse/notes/Sep01C2.pdf
- University of Exeter (Regression)
  http://www.exeter.ac.uk/~SEGLea/psy2005/simpreg.html
  http://www.exeter.ac.uk/~SEGLea/psy2005/basicmlt.html
- University of Hawaii (Regression)
  http://www.soest.hawaii.edu/wessel/courses/gg313/DA_book/node74.html
- University of Southern California (Regression)
  http://www-rcf.usc.edu/~moonr/econ419/econ414_2.pdf
- University of Sussex (Regression)
  http://www.cogs.susx.ac.uk/users/andyf/teaching/pg/regression1/sld001.htm

4.2.5.2 Engineering Build Up

Sometimes referred to as "grass roots" or "bottom-up" estimating, the engineering build up methodology rolls up individual estimates for each element into the overall estimate. The engineers performing the work usually provide these lower level estimates. This costing methodology involves the computation of the cost of a WBS element by estimating at the lowest level of detail (often referred to as the "work package" level) wherein the resources to accomplish the work effort are readily distinguishable and discernable. Often the labor requirements are estimated separately from material requirements. Overhead factors for cost elements such as Other Direct Costs (ODCs), General and Administrative (G&A) expenses, materials burden, and fee are generally applied to the labor and materials costs to complete the estimate. A technical person who is very experienced in the activity typically prepares these engineering build up estimates. The cost estimator's role is to review the grassroots estimate for reasonableness, completeness, and consistency with the program/project GR&A. It is also the cost estimator's responsibility to test, understand, and validate the knowledge base used to derive estimates.

There are also situations where the engineering community provides their "professional judgment," but only in the absence of empirical data. Experience and analysis of the environment and available data provides latitude in predicting costs for the estimator with this method. This method of engineering judgment and expert opinion is known as the Delphi method. Interview skills of the cost estimator are important when relying on the Delphi method to capture and properly document the knowledge being shared from an engineer's expert opinion.

4.2.5.2.1 Calculating an Engineering Build Up Estimate

Exhibit 4-10 illustrates a method for deriving an engineering build up estimate.

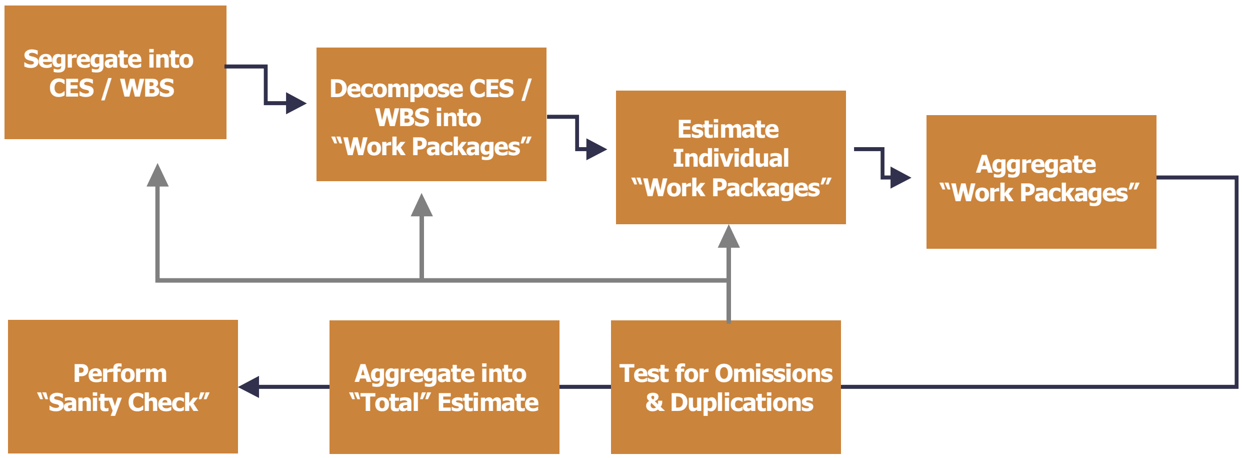

Exhibit 4-10: Method for Developing an Engineering Build Up Estimate

Exhibit 4-11 provides a list of the strengths and weaknesses of using the engineering build up method to develop a cost estimate.

Strengths	Weaknesses
Intuitive.	Costly; significant effort (time and money) required to create a build-up estimate.
Defensible.	Not readily responsive to "what if" requirements.
Credibility provided by visibility into the Basis of Estimate (BOE) for each cost element.	New estimates must be "built-up" for each alternative scenario.
Severable; the entire estimate is not compromised by the miscalculation of an individual cost element.	Cannot provide "statistical" confidence level.
Provides excellent insight into major cost contributors.	Does not provide good insight into cost drivers.
Reuse; easily transferable for use and insight into individual project budgets and individual performer schedules.	Relationships/links among cost elements must be "programmed" by the analyst.

Exhibit 4-11: Strengths and Weaknesses of Engineering Build Up Method of Cost Estimating

4.2.5.3 Analogous System Estimates

Analogous estimates are performed on the basis of comparison and extrapolation to like items or efforts. Cost data from one past program that is technically representative of the program to be estimated serves as the basis of estimate. These cost data are then subjectively adjusted upward or downward, depending upon whether the subject system is felt to be more or less complex than the analogous program. Clearly subjective adjustments compromise completely the validity and defensibility of the estimate and should be avoided. Fit best, linear extrapolations from the analog are acceptable "adjustments." Typically an analogous item is less useful as a technique and is more useful as a data point in a parametric estimate.

This estimating approach is typically used when an adequate amount of program and technical definition is available to allow proper selection, and adjustment, of comparable program costs. With this technique, a currently fielded system (comparable system) similar in design and/or operation of the proposed system is identified. An analogous approach is also used when attempting to estimate a generic system with very little definition.

Taking the fielded system's data, the estimator then adjusts it to account for any differences and then develops the cost of the proposed system. The analogous system approach places heavy emphasis on the opinions of "experts" to modify the comparable system data to approximate the new system and is therefore increasingly untenable as greater adjustments are made. Exhibit 4-12 provides a list of the strengths and weaknesses of using an analogous system method to develop a cost estimate.

Strengths	Weaknesses
Based on actual historical data.	Relies on single data point.
Quick.	Can be difficult to identify appropriate analog.
Readily understood.	Requires "normalization" to ensure accuracy.
Accurate for minor deviations from the analog.	Relies on extrapolation and/or expert judgment for "adjustment factors."

Exhibit 4-12: Strengths and Weaknesses of Analogous Method of Cost Estimating

Complexity factors can be applied to an analog estimate to make allowances including year of technology, inflation, basing modes, and technology maturation. A complexity factor is used to modify a CER for complexity (e.g., an adjustment from an air system to a space system). A traditional complexity factor is a linear multiplier that is applied to the subsystem cost produced by a cost model. In its simplest terms, it is a measure of the complexity of the subsystem being costed compared to the composite of the CER database being used or compared to the single point analog data point being used. The selection of an appropriate complexity factor is a controversial part of the cost estimating process because of the subjectivity involved.

Tips

Complexity Factors

Tables have been prepared by various NASA cost offices as guidelines to design engineers in making these judgments regarding selection of a complexity factor. Although these are not absolute standards, they may be useful as general guidance if the engineer is having difficulty quantifying his/her assessment of the relative complexities.

Source: JSC NASA Cost Estimating Guidelines

How is it calculated

Determining a Value of a Complexity Factor

The most uncomplicated approach to determining a value for the complexity factor of a subsystem is to work closely with the design engineer responsible for that subsystem. The following steps would generally be followed to determine the complexity factor. The design engineer (with the assistance of the cost estimator) would:

1. Become familiar with the historical data points that are candidates for selection as the costing analog,
2. Select that data point that is most analogous to the new subsystem being designed,
3. Assess the complexity of the new subsystem compared to that of the selected analog. This assessment would be in terms of design maturity of the new subsystem compared to the design maturity of the analog when it was developed, technology readiness of the new design compared to the technology readiness of the analog when it was developed, and specific design differences that make the new subsystem more or less complex than the analog (examples would be comparisons of pointing accuracy requirements for a guidance system, data rate and storage requirements for a computer, differences in materials for structural items, etc.),
4. Make a quantitative judgment for a value of the complexity factor based on the above considerations, and
5. Document the rationale for the selection of the complexity factor.

If a CER is used instead of a single point analog, the above process is still applicable. The only difference is that the design engineer would make these assessments with respect to the total data base making up the CER for that subsystem rather than a single data point.

Source: JSC NASA Cost Estimating Guidelines

4.2.5.4 Vendor Quotes/ROM

Often a project or program will involve the use of hardware, facilities, or services for which the costs are readily available from vendors. An example of a vendor quote would be the cost of launch services for a commercial launch vehicle. The use of a vendor quote can apply to any item (e.g., hardware, facility, or service), at any level in the WBS, if the cost of the item plus its integration costs into a NASA system is well known and based on NASA's experience with the vendor and the product/service.

A vendor quote/ ROM estimate might be used when the vendor is willing to provide informal cost information and the cost analyst has concluded that a better cost approach does not exist. The cost estimator would need to determine that the vendor ROM is consistent with the program or project GR&A (e.g., inflated versus constant year dollar, fee included, integration costs included, etc.,) and make appropriate adjustments to the vendor ROM if necessary.

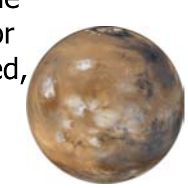

Exhibit 4-13 provides a list of the strengths and weaknesses of using an analogous system method to develop a cost estimate.

Strengths	Weaknesses
Readily available.	Need to have visibility into what is included in the provided cost.
Any WBS item at any level.	Cost need to be adjusted to be consistent with the estimated.

Exhibit 4-13: Strengths and Weaknesses of Vendor Quote/ROM Method of Cost Estimating

4.2.6 Select/Construct Cost Model

Modeling is a systematic approach to analyzing a program or a project that is supportive and quantifiable. The selection of the appropriate cost model to use for a particular project is an important consideration in the cost estimating process.

4.2.6.1 Modeling Environments

Many cost estimating models exist, and, similar to the estimating methodologies, no single cost model can be used for all purposes. Some models are a basic construct to be used as a tool, such as Microsoft Excel. Other models are estimating environments that can be all-inclusive and automate many functions for the cost estimator.

Excel is a powerful, flexible spreadsheet tool that is widely utilized by the Government and the private sector. Due to its popularity, a lot of employees in the industry are savvy users and are delivering impressive models using the formulas, graphs, and Visual Basic functions that are embedded in the software. The Microsoft software package, including Access, Excel, PowerPoint, and Word are compatible with each other, which creates a seamless environment of automated tools.

The advantage of creating your model in Excel is the ability of having a "glass box" model where all formulas and intricacies of your creation can easily be traced. The powerful formula and Visual Basic functions that are part of Excel provide endless avenues of creative model formulation. The ability to transfer the model from one place to another is fluid.

The disadvantage of creating a model in Excel is that the cost estimator needs to build the model from scratch. The analyst must take the time to draw the layout of how the model is going to look and how all the equations are going to fit together. Excel does not have embedded risk tools in the software but add-in tools are available to conduct risk analysis. Some of these add-in risk tools are listed in Appendix K.

4.2.6.2 Modeling and Estimating Tools

There are many cost modeling tools available to assist cost estimators in estimating and organizing costs. It is the cost estimator's responsibility to understand and verify the pedigree and applicability of the model chosen for preparing the estimate. Appendix K provides a listing of many other COTS, Government-Off-The-Shelf (GOTS) and NASA developed tools that are available to the NASA cost estimator. The following paragraphs provide short summaries of two COTS tools that NASA currently holds agency wide licenses with, PRICE and SEER, and more information on NASA developed tools.

4.2.6.2.1 COTS Models

The following estimating environment overviews have been provided by PRICE Systems, LLC and Galorath Incorporated, respectively. See Appendices H and I for additional information on these modeling packages.

PRICE S – is a parametric model used to estimate software size, development cost, and schedules, along with software operations and support costs. Software size estimates can be generated for source lines of code, function points or predictive objective points. Software development costs are estimated based on input parameters reflecting the difficulty, reliability, productivity, and size of the project. These same parameters are used to generate operations and support costs. Monte Carlo risk simulation can be generated as part of the model output. Government Agencies (e.g., NASA, IRS, U.S. Air Force, U.S. Army, U.S. Navy, etc.,) as well as private companies have used PRICE S.

PRICE H, HL, M – is a suite of hardware parametric cost models used to estimate hardware development, production and operations and support costs. PRICE M can be used to estimate electronic module development and production costs. PRICE H can be used to estimate cost associated with equipment being developed and procured by each of the NASA Centers. PRICE HL can be used to generate operations and support costs. The suite of hardware models provides the capability to generate a total ownership cost to support program management decisions. Monte Carlo risk simulation can be generated as part of the model output. Government Agencies (e.g., NASA, U.S. Air Force, U.S. Army, U.S. Navy, etc.,) as well as private companies have used the PRICE suite of hardware models.

J U M P   S T A R T   P r o g r a m

The use of PRICE or SEER products requires the NASA user to setup the PRICE or SEER files by WBS and meaningful configuration of the estimating task. To facilitate this initial effort, each user requires a minimum effort that must be augmented by PRICE and SEER consultants to establish the first few steps of creating PRICE or SEER files. PRICE or SEER consultants will "Jump Start" the estimating and programmatic tasks. See Appendix L for more details and contact information.

SEER-SEM - is a parametric modeling tool used to estimate software development costs, schedules, and manpower resource requirements. Based on the input parameters provided, SEER-SEM develops cost, schedule, and resource requirement estimates for a given software development project. The calculations are based on actual data from thousands of software development projects. SEER-SEM is widely used by both the Government Agencies (e.g., NASA, IRS, U.S. Air Force, SSA, etc.,) and the private companies.

SEER-H – is a hybrid cost estimating tool that combines analogous and parametric cost estimating techniques to produce models that accurately estimate hardware development, production, and operations and maintenance cost. SEER-H can be used to support a program manager's hardware LCC estimate or provide an independent check of vendor quotes or estimates developed by third parties. SEER-H is part of a family of models from Galorath Associates, including SEER-SEM (which estimates the development and production costs of software) and SEER-DFM (used to support design for manufacturability analyses).

4.2.6.2.2 GOTS Models

NASA, alone or in cooperation with other Government Agencies, has developed many cost models to fit a variety of costing situations. In this section a few of these NASA developed cost models are discussed. More NASA developed models and tools can be found referenced in Appendix C and Appendix K. The most common situation is when a study involves a single spacecraft or vehicle and the design data is being developed at the subsystem level. For this case, the NASA/Air Force Cost Model (NAFCOM) is generally the most appropriate model to use.

NAFCOM - contains a comprehensive set of historical cost and technical data for completed NASA programs. These data have been broken down to the subsystem level, normalized, and stratified by mission type, i.e., launch vehicles, manned space vehicles, unmanned spacecraft, and scientific instruments. This facilitates the use of the single point analog approach where the cost estimator builds up the spacecraft or vehicle estimate by selecting the most analogous data point for each subsystem, adjusting for weight and complexity differences, and applying overhead, or "wrap" factors.

Spacecraft/Vehicle Level Cost Model (SVLCM) - is a simple online cost model that provides ROM cost estimates for the development and production of spacecraft, launch vehicle stages, engines and scientific instruments. The SVLCM is a top-level implementation of the NAFCOM.

Advanced Missions Cost Model (AMCM) - is most appropriately used for situations early in the conceptual stages where design data is available only at the total vehicle or spacecraft level and where there are multiple elements for a given scenario.

Architectural Assessment Tool - Enhanced (AATe) - is a NASA Kennedy Space Center operations analysis tool developed to provide operations cost and cycle time estimation for future concepts engages an approach that is at times parametric, analog, and Delphi, as well as Quality Function Deployment (QFD). It is database meets knowledgebase, automated. It fills gaps in operations estimation for reusable launch vehicles at conceptual levels while communicating traceable factors for cost and cycle time to analyst or vehicle developers. It was developed in response to a lack of such tools capable of actually generating (versus allocating from goals e.g., calculators) total costs, fixed and variable, flight and ground, encompassing all aspects of a space transportation systems operation at a high level. This includes direct and indirect costs, mission, launch, and all support element impacts.

There are several other cost models available that can be used as the primary estimating technique or as a "sanity check" against the results of another model's results. These models include:

- GSFC's Multi-Variable Instrument Cost Model (MICM),
- Scientific Instrument Cost Model (SICM),
- Mission System Integration and Test (MSI&T), and
- Parametric Manpower Model.

Unmanned Spacecraft Cost Model (USCM) - NASA also has access to this Air Force model through the AF Space and Missile Systems Center (SMC). This model's applications include unmanned earth orbiting space vehicles, DDT&E, flight hardware (FH), Aerospace Ground Equipment (AGE) and Launch and Orbital Operations Support (LOOS).

Model for Estimating Space Station Operations Costs (MESSOC) - is another product specific model that is available to the estimator through the Space Station Headquarters Support office. MESSOC covers all mature operations costs for Earth-orbiting space stations.

Software Costing Tool (SCT) - is a model uses statistically based cost estimating relationships. SCT is available through JPL that covers NASA manned and unmanned flight and ground software development costs.

Small Satellite Cost Model (SSCM) - is a tool developed and maintained by the Aerospace Corporation. This model applies to system and subsystem level DDT&E and FH costs of newer Class C and D Earth-orbiting small satellites.

The cost estimator should be prepared to defend the choice of cost models. The purpose and level of design detail available will often dictate the choice of cost model or estimating methodology.

4.2.7 Identify Data Required, Data Sources, Obtain Data, Normalize Data

Typically, this is the step in the process where data collection occurs. However, as previously noted, data collection can occur in earlier steps, such as collecting data for regression analysis to support a methodology. Once the cost estimating methodology and cost model are selected, the data required becomes apparent. Sources of data are discussed in this section.

4.2.7.1 Identify Data Required and Data Sources

The cost estimator will work with the Program/Project Manager and members of the technical team to obtain the technical and programmatic data required to complete the cost analysis. The first step is to understand how the project requirements are going to be documented, i.e., what kind of "requirements document" is going to be developed by the project team. Typically, these are contained in a document, or set of documents, such as a CARD. A well-documented set of program/project requirements ensures that the cost estimators are estimating the same product that is being designed by the technical team. If some of the cost model inputs are not explicitly contained in the requirements document, the cost estimator will have to coordinate with the cognizant technical point of contacts to obtain these data by interview techniques and/or by data forms and formats.

4.2.7.2 Data Collection

Data collection is typically one of the most difficult, time-consuming, and costly activities in cost estimating. It is not always clear what data you will need at the beginning of an assignment and data requirements often evolve during the course of developing an estimate. Data sources can be hard to identify and those supplying data can balk at providing detailed cost information. Often, you do not find what is exactly needed and typically there is a story behind the data that is important to understand. It is the estimator's job to recognize that adjustment to the data may be necessary for it to support the needs of a particular NASA Program Office.

4.2.7.2.1 Data Collection Process

Data collection starts on the first day of the assignment and continues throughout the development and documentation of the estimate or analysis. There are seven steps involved in data collection:

1. Understanding the program,
2. Identify potential issues (e.g., schedule, performance, etc.),
3. Identify candidate cost drivers,
4. Identify data types and potential sources (see Exhibit 4-14),
5. Gather data,
6. Visualize data to identify underlying trends, and
7. Evaluate and adjust data (see discussion of normalization).

4.2.7.2.2 Collecting Data Methods

The following are potential mechanisms available to the cost estimator for identifying quantitative cost data:

- Surveys and/or questionnaires,
- Target research (public domain or otherwise),
- Statistics, and
- Specific cost, technical, and programmatic data from primary and secondary sources.

Three Principle Types of Data

Data Category	Data Type	Data Sources
Cost Data	• Historical Costs • Labor Costs • CERs from previous programs	• Basic Accounting Records • Cost Reports • Historical Databases • Contracts (Secondary) • Cost Proposals (Secondary)
Technical Operational Data	• Physical Characteristics • Performance Characteristics • Performance Metrics • Technology Descriptors • Major Design Changes • Operational Environment	• Functional Specialist • Technical Databases • Engineering Specifications • Engineering Drawings • Performance / Functional Specifications • End User and Operators
Program Data	• Development and Production Schedules • Quantities Produced • Production Rates • Equivalent Units • Breaks in Production • Significant Design Changes • Anomalies (e.g., strikes, national disasters, etc.)	• Program Database • Functional Organizations • Program Management Plan • Major Subcontractors

Exhibit 4-14: Data Types and Sources

To collect qualitative data, use:

- Interviews,
- Focus Groups,
- Reviews,
- Meetings, and
- Targeted research (public domain and otherwise).

Based upon the resources, the schedule and the expectations, use as many of these data collection methods as can be supported.

Caveats & Limitations

- Commercial vendors are often the only sources for cost data; their motivation shifts based upon the different phases of acquisition. During pre-award, commercial vendors are motivated to win business, working hard to keep their cost estimates competitive. After award, a commercial vendor's motivate shifts to profitability, alleviating some of the pressure on cost accuracy. Keeping this dynamic in mind is helpful during data collection.
- Requirements growth is another factor influencing rising cost post-award. During the data collection phase, it is critical for the cost analyst to push for the greatest level of specificity.
- Just because it is on the Internet does not make it fact. Attempt to get independent confirmation of data posted on websites.
- Agency analysis initiatives are creating situations where simply gathering information, having everyone use the same information, having the information be the most recent, and having some trace-back capability to the source can become a major success or failure criteria to schedule, cost, and validity of the cost estimate. Further, is the estimate communicated and "stamped" for approval in a configuration controlled process?

4.2.7.3 Data Normalization

Once data is collected it must be normalized for inflation. Exhibit 4-15 defines some common terms used for inflation and escalation.

Term	Definition
Base Year (BY) Dollar	A point of reference representing a fixed price level.
Constant Year (CY) Dollar	Money or prices expressed in terms of values actually observed in the economy at any given time.
Current Year (CY) Dollar	Money or prices expressed in terms of values actually observed in the economy at any given time.
Budget Dollar	Total Obligation Authority (TOA) inflated according to the amount of escalation used in the current budget year.
Then Year (TY) Dollar	TOA that includes a slice of inflation to cover escalation of expenditures over a multiyear period.
Real Year (RY)	Money expressed as spent dollars.
Inflation Rate	The percentage change in the price of an identical item from one period to another.
Outlay Profile	In percentage terms, the rate at which dollars in each appropriation are expected to be expended based on historical experience.
Raw Inflation Index	A number that represents the change in prices relative to a base year of 1.0000.
Weighted Inflation Index	Combines raw inflation indices and outlay profile factors to show the amount of inflation occurring over the entire period needed to expend the TOA.
Composite Inflation Index	A weighted average of the inflation indices for the applicable sub-appropriations.

Exhibit 4-15: Inflation and Escalation Terms Defined

4.2.7.3.1 Inflation

The Systems and Cost Analysis Division in the Office of the CFO at NASA Headquarters provides an annual update of the NASA New Start inflation index (most recent version in Appendix M) to be used to prepare cost estimates for new research and development projects. These inflation indices can be used for:

New Start Inflation Index can be obtained through Chris Chromik in the IPAO. New indices are available in April.

- Inflating cost model results expressed in terms of constant year costs to real year dollars for budgetary or POP purposes,
- Converting from constant dollars expressed in one year to constant dollars expressed in a different year, and
- Normalizing historical cost data expressed in real year (as-spent) dollars to constant year (CY) dollars.

Through escalation, inflation adjusts costs to reflect the decrease in the purchasing power of money. The inflation factor is the "multiplier" used to account for the change in price of a product or service over time. Escalation factor (or weighted inflation) is the "multiplier" used to account for inflation plus the normal occurrence of allocating money in one year and it being spent over a number of years. Exhibit 4-16 demonstrates an inflation calculation example.

For example

NASA Inflation Example

Inputs (FY2002$)		FY02	FY03	FY04	Total
Example 1	BY	$ 100.000	$ 100.000	$ 100.000	$ 300.000
Example 2	CY	$ 100.000	$ 100.000	$ 100.000	$ 300.000
Example 3	TY	$ 100.000	$ 100.000	$ 100.000	$ 300.000
BY Inflation Factor (a)		100.000	100.000	100.000	
Weighted Inflation Factor (b)		100.000	103.100	106.300	
Multiplier (a)/(b)		1.000	0.970	0.941	
Outputs (FY2002$)					
Example 1	BY	$ 100.000	$ 100.000	$ 100.000	$ 300.000
Total		***$ 100.000***	***$ 100.000***	***$ 100.000***	***$ 300.000***
Example 2	CY	$ 100.000	$ 100.000	$ 100.000	$ 300.000
Inflation Factor		1.000	0.970	0.941	
Total		***$ 100.000***	***$ 96.993***	***$ 94.073***	***$ 291.067***
Example 3	TY	$ 100.000	$ 100.000	$ 100.000	$ 300.000
Inflation Factor		1.000	0.970	0.941	
Total		***$ 100.000***	***$ 96.993***	***$ 94.073***	***$ 291.067***

Inflation Table

Code:	108	
Term:	R&D	
Database:	System	
Source:	HQ NASA	
RevDate:	16-Apr-99	
Year	RAW	WTD
2000	94.100	94.100
2001	97.000	97.000
2002	100.000	100.000
2003	103.100	103.100
2004	106.300	106.300
2005	109.500	109.500
2006	112.900	112.900

Exhibit 4-16: Inflation Calculation Examples

4.2.8 Populate Model and Calculate Cost

Once the model has been selected or constructed and the data has been gathered, the next step is to populate the model. Once the model has been populated with the data, according to the GR&A and the data are properly time phased, the model is ready to be run to calculate the cost. Before and after running the model it is important to check and recheck formulas and data entry to ensure accuracy and to document each input and formula for the detail estimate documentation.

4.2.8.1 Time Phasing

Once an estimate has generated a point estimate, it needs to be allocated across the appropriate time period, taking into account the planned execution schedule. This can be done using many techniques, including beta curves (see Appendix N for discussion), historical spreads, engineering judgment, and budget constraints.

4.2.9 Develop Cost Range and Risk Reserves

Developing the cost range and risk reserves and determining how the different ranges affect the different point estimates can be done by conducting a sensitivity analysis. Developing a reserve range and determining the risk adjusted point estimate for probability of occurrence can be done by conducting a risk analysis.

These "What-if" analyses are useful for several reasons:

<u>Determining the project's cost drivers.</u> Analyzing which input variables will have a significant effect on the final cost can help determine which design (or programmatic) parameters deserve the most attention during the definition and design phase of the project.

<u>Estimating the probability of achieving the point estimate</u>. Often it can be demonstrated that the point estimate has a less than 50-50 chance of being achieved when a simulation risk analysis technique is performed using the low, most likely, and high values provided for the input variables.

<u>Establishing reserves</u>. Similarly, by using a simulation risk analysis technique, the analyst can construct a cumulative probability distribution curve ("S" curve) that will provide the probability of not exceeding a specified cost. This methodology than can be used to establish the amount of project reserves that would be required to achieve a desired level of confidence that a project cost would not be exceeded.

<u>Providing a cost range.</u> Inputting a series of low and high values of the input parameters through the cost model can establish the low end and the high end of the cost estimate range. This cost range is often more useful to project management than a point estimate.

4.2.9.1 Sensitivity Analysis

It is recommended that a sensitivity analysis be performed to identify the major cost drivers and assumptions for the range of alternatives. Sensitivity is used to identify cost drivers, i.e., those variables whose changes create the greatest changes in cost. Conducting a sensitivity analysis also ensures that all potential improvements and costs have been captured. Sensitivity is determining how the different ranges of estimates affect the point estimates. For decision-makers a range estimate with an understanding of the certainty of how likely it is to occur within that range is generally more useful than a point estimate. From there a decision can be made with the point estimate from the range with the risk percentage and factors the decision-maker is most comfortable with. Due to the nature of the NASA design and development process there will always be uncertainty about the values of some, if not all, of the technical parameters during the definition phase of a project. Likewise, many of the assumptions made at the beginning of a project's definition phase will turn out not to be accurate. Therefore, once the point estimate is developed, it is often desirable to determine how sensitive the total cost estimate is to changes in the input data.

While sensitivity analyses can occur at any stage of an estimate, it generally makes sense to derive an unconstrained solution that meets all mission objectives initially, then begin to "back off" that solution in the interests of saving money. Care must be taken, however, not to impact the material solution to such an extent that the benefits derived from that solution are significantly altered through introduction of the changes.

4.2.9.2 Risk Analysis

Performing a risk analysis is a mechanism to create the risk adjusted point estimate adjusted for the probability of occurrence. Risk addresses the probability of an event occurring and the consequences surrounding the occurrence.

Cost uncertainly is the confidence we have in our estimating abilities. By the very nature of forecasting into the future, there exists a certain amount of risk and uncertainty with an LCC estimate. Yet, every effort is made to ensure the accuracy of the estimates. As long as the risk is identified, it can be managed and controlled. In fact the decision-maker is actually the one that determines the risk from the probability and the consequences of the risk happening.

To account for the uncertainty and the lack of precision in each of the assumptions, input variable distributions (minimum, most likely, maximum) can be estimated for key cost elements. Once the LCC model is fully developed for each alternative with the input variable distributions, the model can then be subjected to a Monte Carlo simulation.

A Monte Carlo simulation calculates numerous scenarios of a model by repeatedly picking random values from the input variable distributions for each "uncertain" variable and calculating the results. Typically, a simulation will consist of 2,500 to 10,000 iterations. The results of Monte Carlo simulations are risk-adjusted estimates and corresponding statistical estimate distributions. The estimate distributions provide the decision-maker with a range of possible outcomes and bounds, with a minimum and maximum value. (The input variable distributions and cost estimate range is provided with each alternative analysis.)

There are various ways to categorize risks that affect space systems missions. Provided below are definitions for five types of risk, obtained through interviews with the NASA CEC that represent NASA's composite view of risk types. Each program must determine the categories of risk to evaluate.

T y p e s   o f   R i s k

Cost Risk: Cost Risk is the probability that the estimate is correct. Cost risk is defined as uncertainty resulting from the use of a particular cost estimating methodology. Risk due to economic factors, rate uncertainties, cost estimating errors, statistical basis of CER uncertainty, and statistical uncertainty inherent in the estimate can be addressed by examining the uncertainty inherent in the estimating process. A "risk-adjusted" estimate can be created wherein the distribution of likely values for key parameters can be incorporated via Monte Carlo simulations to provide a "range" of likely cost versus a single "point estimate" with no comment on its likelihood of occurrence. Risk adjusted ranges are very useful to decision-makers, however budgets need point estimates. It is recommended that decision-makers should select their preferred point estimate from the risk-adjusted range that the cost estimator provides.

Technical Risk: Technical risk is defined as uncertainty in the system performance or "benefits." Technical Risk is risk associated with programmatic, system, or process requirements, planning, design, implementation or operations to achieve performance objectives within specified constraints. Technical risk may result from an immature technology, use of a lower-reliability component, degree to which products employ the latest standards in technology and design, availability of skilled resources to support the product, and then degree of tailoring required. Technical risk can be reflected in increased costs (to fix the technical problem) and lower overall system benefits.

Integration Complexity Risk: This category includes risks associated with the number of data dependencies, the number of actual interfaces between this module and other modules, and the technical issues regarding programming and application solutions.

Market Risk: This category includes risks associated with the stability of vendors and their software and related tools and services within the market. Market risk may increase or decrease depending on such factors as the number of vendors or products within the market, the degree to which specific products are tested and implemented in a production environment similar to the intended use of the system under consideration, and implementation.

Project Schedule and Programmatic Risk: This category includes risks that the module implementation will be successful and run according to planned schedule. Schedule risk is defined as uncertainty in the project completion or fielding schedule, and the subsequent impact on costs and level of benefits. A stretched-out schedule may increase costs due to extended level-of-effort funding requirements, and result in delivery of systems too late to have the desired effect (reduced benefits). This category also addresses factors such as the thoroughness of project approach and plan, the degree to which plans incorporate risk mitigation techniques, and the impact of not meeting or adjusting the project's anticipated timeline.

Once categories are defined and identified, a high-medium-low scale (shown in Exhibit 4-17) can be used to score the each alternative's risks.

Score	Risk
1	Low Risk
2	Medium Risk
3	High Risk

Exhibit 4-17: Risk Scale

Then, after the analysis, each alternative's numerical score can be converted to a red, yellow or green signal based on the corresponding scale shown in Exhibit4-18.

Score	Benefit	Color
1.0 – 1.7	Low Risk	Green
1.8 – 2.4	Medium Risk	Yellow
2.5 – 3.0	High Risk	Red

Exhibit 4-18: Risk Rating

Finally, a risk-rating summary can be developed to assess risk graphically and numerically. A sample is provided in Exhibit 4-19.

Risk Category	Weight	Status Quo	Full COTS	COTS with Training Interface	Application Cross Service	Full Cross Service
Integration Complexity	40%	2.0	1.7	1.7	2.2	2.5
Market Risk	10%	2.0	1.0	1.0	2.2	1.7
Technical Risk	15%	2.2	1.0	1.0	1.3	2.3
Implementation Project Risk	35%	1.0	1.9	2.0	2.3	2.5
Weighted Average	100%	1.7	1.6	1.6	2.1	2.4
	Color	Green	Green	Green	Yellow	Yellow

Exhibit 4-19: Sample Risk Rating Summary

COTS tools are available to help model risk. These tools (see list in Appendix K) are mostly compatible with the MS Office suite of software applications and generally use Monte Carlo simulations to derive percentages of baseline costs based on the uncertainties in cost methodology, technical feasibility, and schedule. Once parameters are entered for these components of risk, the models will derive a recommended "contingency" value. This value, when added to the baseline estimate, theoretically reflects an equal chance (50%) of the actual system LCC overrunning and under running the point estimate.

4.2.10 Document the Cost Analysis

Cost analysts should document the results of the cost estimate during the entire cost estimating process. This should not be left until the estimate is complete. A copy of the CARD that the cost estimate was based on should also be retained by the CAO. Although standardization of the content and format of the cost estimate documentation across all NASA Centers is unrealistic, it is recommended that each Center maintain as much consistency internally with respect to the documentation content and format as possible since this promotes completeness and quality agency-wide of the cost estimate's documentation.

4.2.10.1 Cost Estimate Documentation Guidelines

The purpose of the cost documentation is to provide a written justification for the program cost estimate. Given the size and importance of programs, the documentation clearly should be viewed as a substantive and professional effort. A general rule-of-thumb is that the final product should provide sufficient information on how the estimate was developed so that independent cost analysts--or other review team members--could reproduce the estimate. The means by which each part of an estimate must be fully explained, and the databases employed must be provided in the documentation or clearly identified. A Comparison Track to identify and explain any deviations between the estimate and the prior estimate should also be included along with a brief summary per alternative being considered.

Tips

Cost Documentation

- When a Cost-Estimating Relationship (CER) is used, it should be presented and its source must be cited fully, or the model and the set of data with which it was calibrated must be cited. A cost estimator reviewing the cost documentation should be able to obtain enough information either from the document or from the sources cited therein to reconstruct the CER and evaluate its associated statistics. CER documentation should include descriptive statistics, such as R-squared, correlation coefficients, T-statistics, relevant range, etc. This information is necessary to assess adequately the applicability of a CER.
- Where subjective judgments (Delphi methodology) are used to adjust estimates made by analogy with other systems or components of systems, the professions of those making the judgments must be identified (e.g., cost analysts, engineers, etc.,) and full citations for the source(s) of the costs of each element in an engineering or "grass roots" estimate must also be cited.
- Present detailed examples of the first and second levels of the cost elements normally included in life-cycle cost estimates for the formulation, implementation, and the Operations and Maintenance (O&M) phases.
- When used in the estimate, actual cost history from past or present contracts or analogous programs should be provided.
- Areas of uncertainty, such as pending negotiations, concurrency, schedule risk, performance requirements that are not yet firm, appropriateness of analogies, level of knowledge about support concepts, critical assumptions, etc. should be presented.
- Sensitivity analysis should be performed to include the cost of changing significant input parameters. Risk analysis should be provided to include risk adjusted point estimates. Crosschecks should be included for all high cost/high risk portions of the estimate.
- Tracking through a comparison or cost track is required when an estimate changes. Documentation must include the specific reasons for the change.

The benefit of a well-documented estimate is that the differences with other cost estimating efforts for the same program/project should be easily reconcilable from the documented information. The value of the documentation and analysis is in providing an understanding of the cost elements so that decision-makers can make informed decisions.

4.2.10.1.1 Detailed Cost Estimate Summary

Documentation should include a qualitative assessment of each line item, along with risk confidence levels for each element. The summary is where the detailed estimate is located. The level of detail varies with the estimate but the rule of thumb is enough detail to be replicable by another estimator. Supporting data too complex for this section should be included in the appendix.

Items to be Included in a Detailed Cost Estimate Summary:

a. Primary Methodology and Models: Identify the basis for using a particular method and model. Describe the process validate the new CER, if necessary. For each model used, all details involving parametric input or output including adjustments. It is desirable to submit a softcopy of the cost model with the hardcopy estimate.

b. Cost Estimate to include definitions of the cost elements, a description of how the cost was derived, definition of input variables, list of values assigned to input variable, mathematical formulas used, list of cost factor drivers per cost element, and data sources, data obtained and adjustments made to the data.

c. Risk Assessment to include the range of costs, either by utilizing statistics or expert opinion. The use of a random (+/-) is not sufficient.

d. Cost Drivers to include the key drivers that focus on performance, reliability, maintainability, and general operations should be included. Each driver should be looked at independently of the other.

e. Sensitivity Analysis that should focus on the cost changes due to movements within the operating Parameters. As with risk assessment, a random (+/-) will not suffice. If numerical analysis isn't possible qualitative analysis should be performed. Results should be given in such a manner that it focuses attention on the cost impact for each element within the system.

4.2.10.1.2 Lessons Learned

Lessons learned are often spoken about, however, they are not documented and shared often enough. They are important to build consistency and to ensure credibility. Methodology, assumptions, etc., may prove to be invalid, incomplete, or right on target. This section should highlight those areas. Additionally, the results of the cost estimate should provide lessons learned in the area of general cost information. For example, a lesson learned might be that system costs can be reduced or eliminated by ordering in scale. Learning curve lessons learned are those cost savings lessons that are achievable and applicable regardless of the program. Customer feedback is also important to incorporate in the lessons learned. Most importantly, lessons learned should be shared with the cost estimating team and the NASA CEC to ensure better estimates in the future. The NASA Lessons Learned Information System (LLIS) can be consulted before and during an estimate. At the completion of the estimate, the LLIS should be populated with lessons learned from the estimate. As in the case of documenting the estimate, it is important to document lessons learned during the process. It is also advisable and beneficial to have a team meeting at the end of an estimate to brainstorm and identify lessons learned for future estimates. See Appendix O for a different view of NASA cost estimating and analysis lessons learned.

http://llis.nasa.gov/

NASA Lessons Learned Information System

4.2.11 Present/Brief Results

The cost estimator should prepare briefing material and supporting documentation to be used for internal and external presentations as appropriate. As with the cost estimate documentation, while it may not be realistic to standardize the content and format of the cost analysis briefing charts across all NASA Centers for all estimate types, it is again recommended that each Center maintain as much consistency internally as possible since this facilitates understanding during the management review process and promotes completeness and quality of the cost estimating and analysis documentation.

Thorough documentation is essential for a valid and defensible cost estimate. Cost presentation documentation provides a concise, focused illustration of key points that should direct the reader's attention to the cost drivers and cost results.

4.2.11.1 Defending the Estimate

Cost estimates are used as baseline rationale to develop budget submissions for Presidential and Congressional approval. A budget is partly subjective; to increase the validity of requested dollars, a program that uses a valid cost estimate greatly improves the defensibility of a budget request. This is due to the fact that with a detailed cost estimate, there is little room for hiding money by asking for too much money. Similarly, a detailed cost estimate will show impacts to the program if allocated too little money. Quality, risk, and sensitivity analyses along with thorough documentation and a consistent briefing format are all important factors when defending an estimate.

4.2.12 Update Cost Estimates on a Regular Basis

Cost estimates must be updated whenever program content changes. By accomplishing a cost estimate on proposed program alternatives, the Program Office can determine the cost impact of the alternatives. Keeping the estimate up-to-date helps to defend the estimate, reduce updated estimate turn-around time, and gives the decision-maker a clearer picture for "what if" drills or major decisions.

4.3 Cost Estimating as a Quality Process (ISO 9000 Interrelationship)

The emphasis that all of the NASA Centers and organizations place on achieving and maintaining ISO 9000 certification reflects a commitment to implement high quality work processes at all levels. This emphasis also applies to the NASA cost analysis process. Each CAO should ensure that its processes conform to its Center's Quality System processes and requirements. Guidelines have been developed through the CEWG for implementation of a standard set of metrics and customer feedback formats.

Cost Analysis Metrics - Developing and implementing an effective method of assessing the effectiveness and efficiency of the performance of NASA CAOs is important to the improvement in the state-of-the-art of our profession. A well-defined and consistently applied set of performance metrics promotes professionalism and continuous improvement in cost analysis policies, standards, and processes.

Customer Focus - Cost Analysis is a service-oriented activity with identifiable customers and products. Obtaining and assessing customer feedback is an important step in the continuous improvement process. Appendix P presents a suggested Customer Survey format that can be used by the NASA CAOs.

The Customer Feedback Form found in Appendix P was developed by Robert Sefcik at GRC. Customer feedback is another important aspect of the Lessons Learned process. Results of this survey can provide valuable insight to improve the cost estimating process in the future. The JSC cost team distributes a Customer Feedback form to their clients to track their performance and client satisfaction. This metric tool has been successful tracking client satisfaction.

5 Financial Analysis Techniques

In the previous section, the cost estimating techniques associated with generating a point estimate are presented. In this section of the document, various valuation metrics are presented to give an overview of the different financial analysis techniques available to NASA's CEC. Additionally, this section presents a discussion about Economic Analyses (EAs). Many useful references to augment the discussion in this section are found in Appendix C.

5.1 Financial Calculations

The formulas discussed in this section are foundation building calculations to determine the benefit to cost ratio valuation metric. Program Manager's in today's environment need to be armed with as much data and information as possible to make decisions and to justify their programs. Financial and performance metrics serve as tools to help interpret the cost data derived in the estimate.

5.1.1 Present Value and Discounting

The present value concept captures the time value of money by adjusting through compounding and discounting cash flows to reflect the increased value of money when invested. The present value of a cash flow reflects in today's terms, the value of future cash flows adjusted for the cost of capital. In essence, the time value of money reflects the fact that money in hand today is more *valuable* than an identical amount of money received in the future and that benefits and costs are worth more if they are realized earlier.

How is it calculated

The present value of an investment is calculated from the time series of projected cash flows using discount rates specified in the OMB Circular A-94, Appendix B[7] (http://www.whitehouse.gov/omb/circulars/a094/a094.html). To estimate net present value (see Section 5.1.2), future benefits and costs must be discounted. Discount factors can be reflected in real or nominal terms as defined by OMB Circular A-94 Appendix C. The discount rate used depends on the type of dollars to be adjusted:

Real Discount Rates—Adjusted to eliminate the effects of expected inflation used to discount *Constant Year* dollars or real benefits and costs. A real discount rate can be approximated by subtracting expected inflation from a nominal interest rate.

Nominal Discount Rates—Adjusted to reflect expected inflation used to discount *Then Year* (inflated) dollars or nominal benefits and costs.

Discounting translates projected cash flows into present value terms using specified discount factors. As illustrated in Exhibit 5-1, the ***discount factor*** is equal to $1(1+i)^n$ where *i* is the interest rate and *n* is the number of years from the date of initiation for the project.

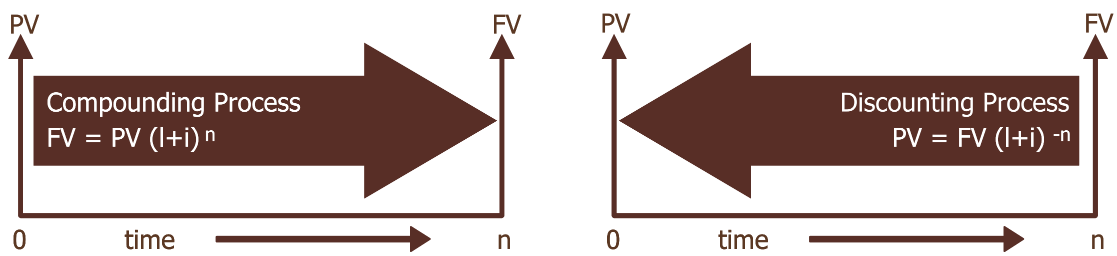

Exhibit 5-1: Compounding and Discounting

7 OMB Circular A-94 provides specific guidance on the discount rates to be used in evaluating Federal programs whose benefits and costs are distributed over time. Its guidance serves as a checklist as to whether an agency has considered and properly dealt with all the elements for sound benefit-cost and cost-effectiveness analyses.

Exhibit 5-2 provides an example of how discounting is applied.

For example

If cost is the only deciding factor, which investment should the organization invest in?

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Project A Cost	$100	$100	$100	$100	$100	$500
Project B Cost	$500	$ ---	$ ---	$ --	$ --	$500
Project C Cost	$ ---	$ ---	$ ---	$ --	$500	$500

The organization should invest in the project with the lowest discounted cost stream. In the example below, Project C has the lowest cost in terms of present value. For example, you need $500 today for Project B. Alternatively, you could put $449 in a bank today and receive the $500 you need in year 5 for Project C. Economists contend you are better off with Project C because you can do something else with the $51 you did not put in the bank.

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Program Year	0	1	2	3	4	
Discount Factor	1.0000	0.9737	0.9481	0.9232	0.8989	
Project A PV Cost	$100	$ 97	$ 95	$ 92	$ 90	$474
Project B PV Cost	$500	$ ---	$ ---	$ ---	$ ---	$500
Project C PV Cost	$ ---	$ ---	$ ---	$ ---	$449	$449

Exhibit 5-2: Discounting Application

5.1.2 Net Present Value (NPV)

Net Present Value (NPV) is a project's net contribution to wealth and is the difference between the discounted present value of benefits and the discounted present value of costs. The net present value indicator provides a measurement of the net value of an investment in today's dollars. OMB Circular A-94 establishes net present value as the standard criterion for deciding whether a government program can be justified on economic principles. According to OMB Circular A-94:

> "*net present value is computed by assigning monetary values to benefits and costs, discounting future benefits and costs using an appropriate discount rate, and subtracting the sum total of discounted costs from the sum total of discounted benefits. Discounting benefits and costs transforms gains and losses occurring in different time periods to a common unit of measurement. Programs with positive net present value increase social resources and are generally preferred. Programs with negative net present value should generally be avoided.*"

The accept reject criterion for the NPV is as follows:

NPV > 0	→	Accept
NPV < 0	→	Reject

NPV is a predictor of profitability, determining when the investment will generate sufficient cash flows to repay the invested capital and provide the required rate of return on that capital. Because all cash flows are discounted back to the present time, the NPV compares the difference between the present value of the benefits and costs and takes into account the opportunity costs of both cash flows.

? How is it calculated

In the most general terms (again consistent with OMB Circular A-94), NPV is defined as the difference between the present value of benefits and the present value of costs. All costs and benefits are adjusted to "present value" by using discount factors to account for the time value of money.

Mathematically, the NPV is calculated as shown:

PV(Annual Benefits)
− PV(Annual Cost)
NPV

The benefits referred to above must be quantified in cost or financial terms in order to be included in the above equation. See Section 6 for a discussion of quantifying benefits.

For most government generated cost estimates, discount rates provided in OMB Circular A-94 are used to discount all cash flows as shown:

[PV (Internal Project Cost Savings, Operational) + PV (Mission Cost Savings)]
- PV(Initial Investment)
NPV

financial analysis techniques

5.1.3 Payback Period and Break-Even Analysis

The payback period is the time required for the cumulative value of savings to be equal to the cumulative value of investment. The payback period helps to answer the question "how long will it take to make back the money spent on the investment?" The payback period measures the time (i.e., years, months) needed to recover the initial investment and break even.

One of the main benefits of the payback period indicator is that it identifies projects that generate benefits occurring *early* in the life cycle. Because out-year benefits are often less certain than benefits that occur early in the life cycle, the payback period is valuable as a ranking indicator when deciding between two investments. Decision-makers at NASA must then decide if the payback period is appropriate considering the organization's other investment opportunities.

How is it calculated

Computing the amount of time it takes for a project to pay for itself (or return its initial investment) is another commonly used criterion for selecting among alternative courses of action in an investment analysis.

The basic question to be answered is at what point in time does:

$$\frac{\text{(Internal Project Cost Savings, Operational)} + \text{(Mission Cost Savings)}}{\textbf{(Initial Investment)?}}$$

In the simplest of cases, the benefits (or returns) begin predictably at the completion of the investment phase and occur in an equal amount each time period. However, for large projects that take years to complete, benefits begin accruing prior to completion of the investment phase and do not occur in equal annual amounts. In both simple and complex situations, the Payback Period in years, *x*, can be found using the following formula (where *t* = time periods in years):

$$\text{PV(Initial Investment)} = \sum_{t=1}^{t=x} \text{PV(Operational Savings + Mission Savings)}$$

5.1.4 Return on Investment (ROI)

In the financial community, the strict meaning of ROI is "Return on Invested Capital." Most business people, however, use "ROI" simply to mean the incremental gain from an investment, divided by the cost of the investment. In this sense, an investment that costs $1,000 and pays back $1,500 after a defined period of time has a 50% ROI.

How is it calculated

ROI is the net benefit expressed as a percentage of the investment amount:

$$\text{ROI} = \frac{\text{NPV}}{\text{PV Investment}}$$

Tips

ROI

Three ways to maximize the ROI of an investment include

Minimizing Costs	Maximizing Returns	Accelerating Returns

A relatively small improvement in all three may have a major impact on overall economic return of the investment.

The following paragraphs describe various ROI metrics.

5.1.4.1 Savings to Investment Ratio (SIR)

To compare the cost of alternatives, ROI is often the most effective measure as it provides a means of comparing alternatives with different expenditure streams. As its name implies, this popular ROI metric represents the ratio of savings to investment.

How is it calculated

Referring back to the NPV (see section 5.1.2), "Savings" represents the benefit term and "Investment" is the cost term. In the SIR calculation, "savings" are generated by adding the Internal Operational Savings and Mission Cost Savings. The flow of costs and cost savings into the SIR formula is as shown in Exhibit 5-3.

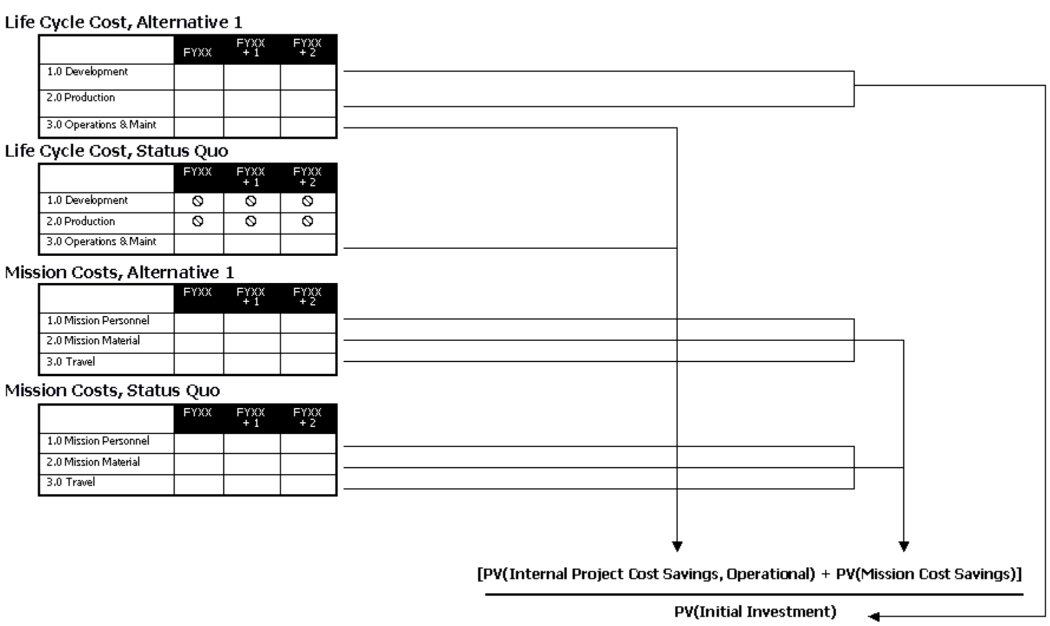

Exhibit 5-3: Calculating the Savings to Investment Ratio

5.1.4.2 Benefit to Cost Ratio

Another often-used ROI metric is referred to as the Benefit to Cost Ratio (BCR). The BCR measures the discounted amount of benefits that the project generates for each dollar of cost.

How is it calculated

BCR is calculated by following the formula

$$\frac{\text{benefits}}{\text{cost}}$$

To differentiate BCR from the SIR, BCR is defined in the manner shown in Exhibit 5-4.

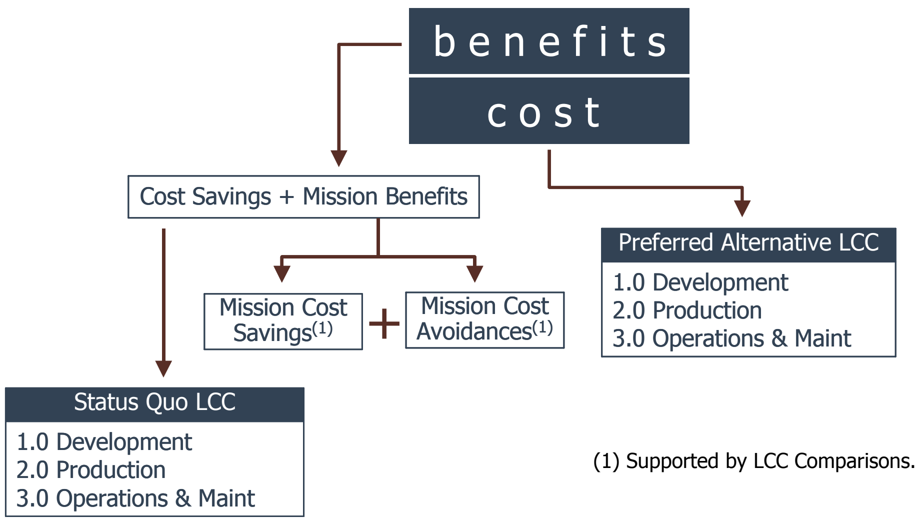

Exhibit 5-4: Definition of the BCR

The computational element of this ratio that is not so intuitive is the recognition that the costs saved in the numerator of the BCR are represented by the status quo LCC estimate in its entirety. To calculate this ratio correctly, all costs associated with maintaining status quo system(s) until the preferred alternative is fully fielded and any legacy systems are abandoned and "turned off" must be included in the Preferred Alternative costs. In the WBS shown above, any phase-out costs for existing systems would need to be included in the O&M estimate for the preferred alterative. In effect, WBS 3.0 in the preferred alternative estimate would present, from an operational cost perspective, the transition from relying on an existing solution to a new one.

Caveats & limitations

In practice, the BCR metric has been problematic because it is so general in its specification. The simplicity of the calculation is deceptive because neither the composition of the numerator nor the denominator has been universally defined or accepted. For example, there is no reason conceptually that you could not define the BCR terms exactly as done in the SIR calculation. Since this computation of the ratio was not so explicitly described when it was promulgated, its definition among practitioners of cost-benefit analysis varies. The cost estimator should establish upfront agreements with the decision-maker prior to conducting the analysis.

5.2 Economic Analysis (EA)

An EA can be applied to all decision processes dealing with at least two possible ways of meeting a requirement. An EA systematically identifies the costs and benefits of each future course of action under consideration. The EA process described herein is a general approach that is applicable to simple as well as complex problems. EAs facilitate the decision-making process by providing a strong analytical framework for evaluating alternatives, identifying costs and issues, highlighting implications of individual alternatives, identifying variables that drive results, assessing risks, uncertainties, and sensitivities of assumptions and costs, and suggesting recommendations. Since EAs focus on the present point in time and forward, they traditionally do not include sunk costs. Exhibit 5-5 illustrates the steps that comprise the EA process.

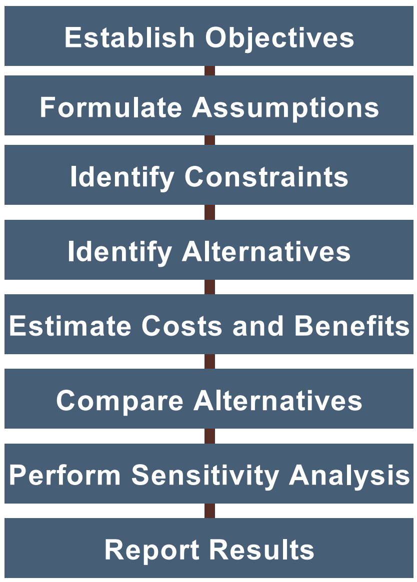

Exhibit 5-5: Economic Analysis Process

5.2.1 Why Conduct an EA?

An EA should be developed for all new or ongoing programs or activities when there is a choice or trade-off between two or more alternatives. Prior to initiating an EA, an Economic Analysis Development Plan (EADP) should be developed. The EADP should include, at a minimum, the mission, background, purpose, constraints, assumptions, cost element structure, cost and benefit estimating methodology, high-level system description, and configuration, schedules, and issues. For a project of high dollar value or high visibility, the EADP should be relatively detailed and should be provided for approval to the decision-maker and other participants in the review/validation process before the analysis is performed.

Ongoing programs should be assessed periodically for their cost-effectiveness. These assessments entail a comparison of actual performance with the approved program/project. To do this, an update to the program's EA is often required. The update must reflect the current status of the program and consider actual costs and benefits experienced to date. Actual data used in program evaluation will also form a sound basis for updated estimates of future costs and benefits.

Caveats & limitations

Exceptions to the requirement to prepare an EA may occur when:

- NASA instructions or directives waive the requirement (e.g., equipment age or condition replacement criteria); and/or
- The requirement is an environmental, hazardous waste reduction, or Federal, state, or local regulatory agency mandate, including directed action by higher NASA authority, which precludes choice or trade-off among alternatives.

In all cases, the efforts expended on an EA must be commensurate with the benefits to be gained from performing the EA. While there are no exemptions based on dollars alone, common sense must be used to determine the appropriate level of effort.

5.2.2 Components of an EA

An EA is a systematic assessment of the value of alternative solutions to a specific mission requirement in terms of comparative costs and benefits. Exhibit 5-6 illustrates the components of an EA product report.

- Objectives
- Assumptions
  - Time considerations
  - Economic life
  - Project life
  - Technological life
- Constraints
- Alternatives
  - Status quo
  - Other feasible alternatives
- Data and Sources
  - Benefits data – Cost estimating data
  - Cost estimating relationships
- Costs
  - Recurring
  - Nonrecurring
  - Base Year dollars
  - Then Year dollars
- Benefits
  - Quantifiable
  - Nonquantifiable
- Alternatives comparison
- Sensitivity, risk/uncertainty analysis
  - Sensitivity analysis
  - Risk/uncertainty
- Economic indicators
  - Savings/investment ratio
  - Benefit/cost ratio
  - Benefit/investment ratio
  - Break-even point
- Conclusions
- Recommendations

Exhibit 5-6: Key Economic Analysis Components

Listed in Exhibit 5-7 are some of the questions that should be answered when conducting an EA.

Organizational	Workload Statistics	Facilities	Personnel
What processes will be effected by the investment?	What resources are associated with performing the process?	Where do the activities take place and are changes to the physical environment required?	What staff is involved with the process and how will they be affected?
What new processes will be put in place because of the investment?	How will performance be affected by the investment?	Are appropriate communication channels in place to support the investment?	Does the organization have the appropriate personnel to support the new investment?
Does the investment improve the operations of the organization?	Will the investment improve the processes or just speed them up?	Is there technology associated with the investment and is the financing of the technology appropriate for the organization?	Who will be responsible for continuing to monitor the investment's return to the organization?
Can the improvements in the processes be quantified and dollar valued?			

Exhibit 5-7: Areas to be Investigated in an EA

At a minimum, any EA must contain the:

- Identification of the mission-related objective(s). This should be consistent with the existing requirement.
- Identification of assumptions with underlying rationale explained in the analysis.
- Identification and full explanation of the constraints (assumed or imposed).
- Identification of a status quo (if applicable) and all feasible alternatives:
  - Alternatives that could fill the gap (or gaps) between where a system or program is now and where it wants to be in the future should be developed. All options to a program's stated goals and/or mission requirements should be captured and considered. Cost and feasibility should not preclude an alternative from consideration.
  - From the list of all potential alternatives, a process of narrowing down alternatives to a manageable number of alternatives should be done via an assessment of the status quo system (hardware, software and infrastructure) and the proposed alternative system(s). To develop a short-list of alternatives, each candidate alternative should be evaluated using non-financial, qualitative factors.
  - If a candidate alternative is eliminated, specific reasons for dropping that alternative must be documented in the analysis.
- Identification of the cost estimating methodology used and all data sources.
  - Data sources can include reviewing technology inventories, architectures, CONOPS, functional requirements, business processes, financial analysis of program data, literature searches, surveys from the stakeholders and users, market research, and interviews.
- An estimate of all anticipated costs, both direct and indirect, over the economic life of the project for each alternative, including the Status Quo.
  - Perform a sensitivity, risk, and/or uncertainty analysis for those costs, cost factors, assumptions, and constraints that could affect a course of action.
- Benefits identified and analyzed in sufficient detail to indicate their contribution to mission accomplishment. Benefits should be quantified whenever possible. Non-quantifiable benefits, such as health or safety, should be thoroughly identified and documented.
- Results and recommendations should be either fully supported with relevant source material and or documentation.

Once each alternative is assigned a composite benefits score, the alternative with the greatest benefit-to-cost ratio is, by definition, the most cost effective. Still, the most cost-effective alternative might not be the best or recommended alternative. Alternatives should be compared to one another, as well as to the status quo, so that a recommendation can be formulated. There are several decision support tools on the market today that can help in this process. See Appendix K for a list of these tools. Additionally, there are other GOTS packages available to NASA, such as ECONPAK, an Army-developed economic analysis tool selected to evaluate construction of facilities projects.

Caveats & limitations

EA Limitations

Many external factors such as safety, health, pollution control, political constraints, and national priorities influence making economic decisions. Whenever possible, these factors should be considered either as quantifiable or non-quantifiable. Every factor has a value and it is up to the estimator to address as many of those influencing factors as possible. If properly prepared, the EA will provide the best answer as to whether or not a program is beneficial, or whether a program/project should be approved or disapproved. However, an EA will **not:**

- Produce results that are more valid than the data used in the analysis.
- Make final decisions.
- Be applied with cookbook precision; instead it should be tailor-fit to the problem.
- Provide relevant solutions to irrelevant questions and problems.
- Predict political and non-economic impacts.
- Provide a substitute for sound judgment, management, or control.

5.2.3 EA Types

In this section, various types of EA are described.

5.2.3.1 Analysis of Alternatives (AoA)

An analysis of alternatives (AOA) broadly examines multiple elements of project/program alternatives including technical risk and maturity, and costs. For example, an AoA may be useful in examining cost performance trades at the system demonstration interim progress review. AoAs are intended to illuminate the risk, uncertainty, and the relative advantages and disadvantages of the alternatives being considered; show the sensitivity of each alternative to possible changes in key assumptions; and aid decision-makers in judging whether or not any of the proposed alternatives offer sufficient operational and/or economic benefit to be worth the cost. For most systems, the analysis should consider the total lifecycle costs and baseline against the system(s) that the acquisition program will replace. The analysis shall explicitly consider continued operations and support costs of the baseline; however, in some cases there will not be an existing system to use as a baseline.

An AoA contains a three-part analysis consisting of:

- **Technical Quantification of Alternatives**
- **Cost Quantification of Alternatives**
- **Analysis of Technical Characteristics within a Cost Framework**

Optimally, a small Integrated Product Team (IPT) consisting of project engineers and cost estimators perform the AoA.

5.2.3.2 Business Case Analysis (BCA)

A business case must adhere to OMB Circulars A-11, *Preparing and Submitting Budget Estimates*, A-130 *Management of Federal Information Resources*, and Clinger Cohen, and also follows Circulars A-94[8], *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* (http://www.whitehouse.gov/omb/circulars/a094/a094.html), and Circular A-76[9], *Performance of Commercial Activities* (http://www.whitehouse.gov/omb/circulars/a076/a076s.html). OMB A-76 identifies burden rates of Federal employees.

OMB Circular A-11, Part III (http://www.whitehouse.gov/omb/circulars/a11/2001_A-11.pdf) provides the framework to guide Federal Agencies through the process of formulating a BCA and ultimately the budget submission. Major capital investments proposed for funding must:

- Support the core mission;
- Support work redesign to cut costs, improve efficiency, and use of off-the-shelf technology;
- Be supported by a cost benefit analysis based on both qualitative and quantitative measures;
- Integrate work processes and information flows with technology to achieve the strategic goals;
- Incorporate clear measures to measure not only a project's success but also its compliance with a security plan; and
- Be acquired through a strategy that allocates the risk between the Government and contractor, and provides for the effective use of competition.

A BCA is an EA that supports investment decisions involving what to buy, how much to spend, what returns to expect, and when to implement. A BCA presents the expected cash flow consequences of competing alternatives, over time, and includes the assumptions for quantifying benefits and costs. A BCA enables decision-makers to base investment decisions on facts while discovering the potential risks and rewards of the specific project. The true value of the BCA is not as a document to protect against audits; but rather, its importance resides in its ability to clarify the thinking of decision-makers as they evaluate the merits of alternative investments for the organization. This distinction is important in deciding the best type of analysis to perform, and the level of detail required in the cost and benefit data. For more information about legislative initiatives that call for BCAs, see Appendix Q.

5.2.3.3 Competitive Sourcing Studies (A-76 Studies)

Competitive sourcing is an EA conducted to determine the most cost effective method of obtaining services that are available in the commercial market. Agency missions may be accomplished through commercial facilities and resources, Government facilities and resources or mixes thereof, depending upon the product, service, type of mission and the equipment required. The prevailing regulations for the Competitive Sourcing studies is the OMB Circular No. A-76 Revised Supplemental Handbook, Performance of Commercial Activities, revised 1999.

[8] *OMB A-94 identifies the preferred discount factors and shows how to calculate inflation factors.*
[9] *OMB A-76 identifies burden rates of Federal employees.*

5.2.3.4 Cost Benefit Analysis

A Cost Benefit Analysis (CBA) is an EA called for in OMB Circular A-94, where the cost and benefits of each alternative are compared to determine the ROI for the program/project. A CBA balances two equally important components: the LCC estimate for each alternative and the estimated benefits of each alternatives. The LCC typically focuses on the investment requirements, O&M cost, as well as disposal cost for each alternative. The benefits analysis focuses on the benefits realized from the investment.

5.2.3.5 Environmental Quality Economic Analyses (EQEA)

EQEAs support decision-making associated with environmental quality costing alternatives. Environmental quality costs are those costs that are specifically related to activities including pollution prevention, compliance, restoration, and conservation. NASA NSTS 22254, Method for Conduct of Space Shuttle Program Hazard Analyses provides specific guidance related to conducting an EQEA.

5.2.3.6 Functional Economic Analysis (FEA)

This type of EA documents an entire functional process or sub-process, such as the use of alternative launch vehicles, etc. It requires a risk assessment of each alternative solution, requesting a high and low estimate for each cost element and subsequent probability distribution of expected costs.

6 Benefits Assessment & Analysis

In this section, a description of the benefits assessment and analysis process is provided. As indicated in the two previous sections, assessing benefits is a critical skill required of all NASA cost estimators.

Exhibit 6-1 presents an understanding of the relationship among costs, benefits, and ROI. An integral part of the cost estimate is an independent assessment of the benefits associated with the investment. Benefits derived from an investment, along with the cost, provide a true picture of the impact of the investment. Determining the benefits associated with a program/project is vital to the Program Manager, who has to justify the cost by showing how it helps to meet the project's mission, objectives, and goals. Ultimately, the benefits analysis, along with the cost estimate, are used together to identify how to measure the attainment of the goals and objectives to "score" each alternative on the extent to which it satisfies those goals and objectives.

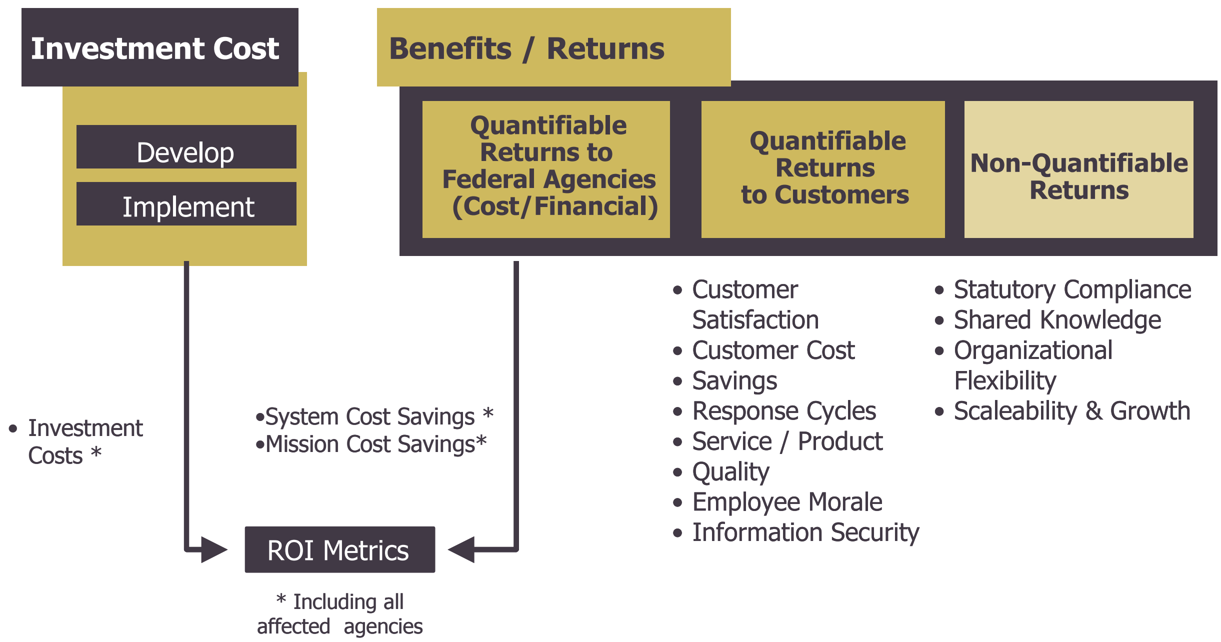

Exhibit 6-1: Relationship Among Costs, Benefits, and ROI

6.1 Estimating and Evaluating Benefits

The process of identifying and quantifying benefits is often the most difficult step in conducting a benefits analysis. A benefits analysis identifies the benefits, both quantitative and qualitative that are used as part of the evaluation criteria. Typically, some benefits may be characterized in financial terms, while other benefits may not be quantified in cost or financial terms[10]. To the fullest extent possible, benefits are identified and quantified for each alternative. Normally, it is assumed that there are varying levels of benefits for each alternative under consideration in addition to varying costs.

It is important to follow a disciplined approach when defining benefits.

10 *This can also be called non-monetized or non-dollarized benefits.*

Exhibit 6-2 illustrates a decision tree that can be used in identifying and quantifying benefits.

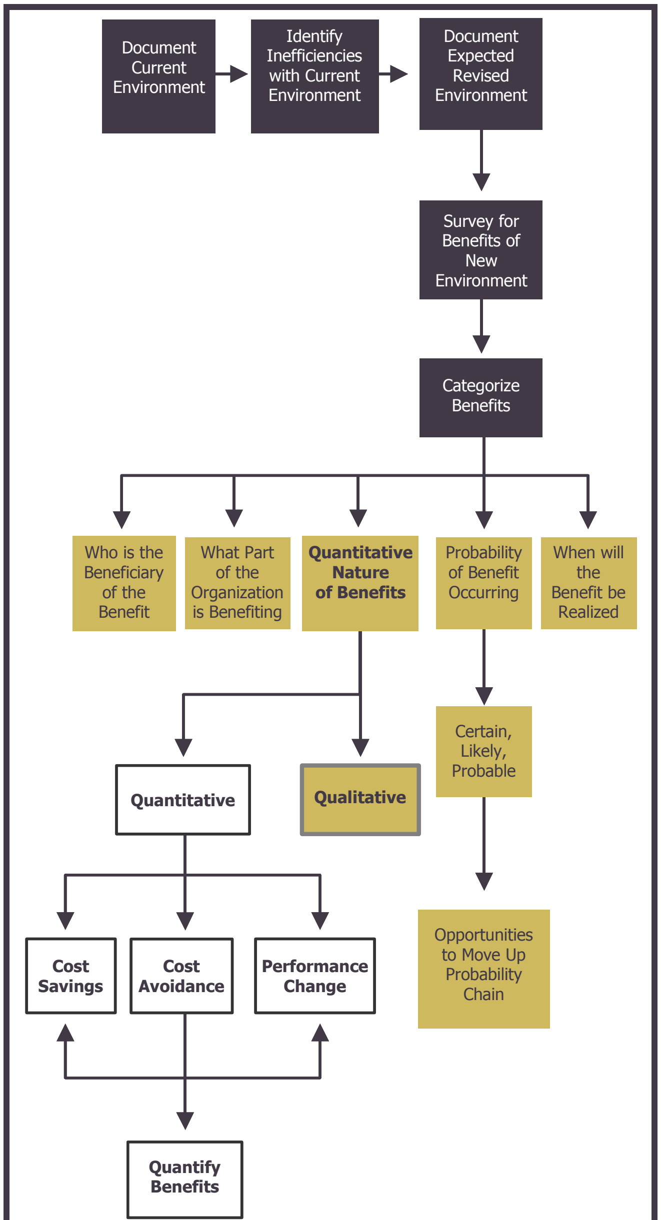

Exhibit 6-2: Decision Tree for Identifying and Quantifying Benefits

Exhibit 6-3 provides a list of sample questions that can be used to determine the existence of benefits.

Simplicity	Will operations be simplified or made more complex?
Speed	Will you be able to respond more quickly to requests?
Redundancy	Will the investment reduce redundant tasks?
Accuracy	Does the system improve error rates or accuracy of information?
Reliability	Will the new system increase the reliability of the processes?
Adaptability	Is the investment adapting to recognized standards?
Retirement	Is the system replacing existing systems?
Morale	Will the new system improve the working environment?
Management Effectiveness	Will the system improve the ability to manage decisions?
Production	Will capacity increase and can more be done with less?
Quality	Will a better product or service be produced?
Versatility	Will the scope and ability of the staff increase because of the system?
Flexibility	Will the staff be able to respond to a greater number and variety of requests?
Facilities	Can facility space be reduced or eliminated?
Security	Will security and the ability to protect information increase?
Consistency	Will the quality of the service or product become more consistent?
Administrative Actions	Will the amount of administrative work increase or decrease?
Materials & Supplies	Will the amount of materials and supplies decrease?

Exhibit 6-3: Benefit Questions

6.1.1 Quantifiable Benefits

Quantifiable benefits are those that can be measured or assigned a numeric value, such as dollars, physical count of tangible items, time, revenue, or percentage change. Dollar valued benefits comprise cost reductions, cost avoidance, and productivity improvements. Quantifiable benefits are calculated by subtracting the cost of an alternative from the cost of baseline operations over the period of the estimate. The difference is the "savings," often referred to as the ROI.

6.1.2 Non-Quantifiable Benefits

Non-quantifiable benefits may include enhanced performance, reliability, utility, consistency and compatibility throughout the enterprise, improved quality, enhancement of best practices, adherence to statutory and regulatory requirements, and enhanced modernization. Exhibit 6-4 illustrates the major difference between quantitative and qualitative measures.

	Term	Example
Quantitative	Ability to be valued or measured in some numerical term such as dollars, time, or capacity.	Installing a barcode scanner at a grocery store saves each clerk an average of 3 minutes per customer. Need fewer clerks.
Revenue	An indirect monetary return resulting from the investment	Purchasing a classic car that can also be rented out for a fee.
Cost Avoidance or Cost Savings	A reduction or elimination of an expense that would likely occur at some point in the future.	Connecting several local grocery stores with a computer network reduces postage and travel costs.
Qualitative	Inability to place a numerical value on a perceived improvement. Place in terms of quality or improvement in mission.	Investing in a stereo system that plays soft music helps customers relax while they shop. (*This could lead to a quantified benefit of repeat business)*

Exhibit 6-4: Quantitative vs. Qualitative Measures

6.1.3 Characterize and Determine Benefits Value

Exhibit 6-5 illustrates a sample method of numerically scoring qualitative benefits. Qualitative benefits can then be assessed as they relate to a program's business or functional drivers. Specific examples of how each alternative supports these drivers should be included in the benefits analysis write up. Based on these examples, each alternative can be identified as fully meeting, partially meeting, or not meeting each of the functional drivers.

Driver	Fully Meets (3)	Partially Meets (2)	Does Not Meet (1)
1. Timely & consistent information for management decisions	***Score 3*** Provides a single data/reporting source. AND Data can be consolidated to meet the needs of multiple organizations at the same time. AND Provides tools for data analysis or reporting. Information is available in timely fashion (real-time or as needed). Provides a single set of agency systems that reduce the amount of repetitive data entry. The system will create a consistent and standard set of data.	***Score 2*** Provides single data/ reporting source. OR Data can be consolidated to meet the needs of multiple organizations at the same time, OR Provides tools for data analysis or reporting. OR Information is available in timely fashion (real-time or as needed). Provides a minimal set of systems with some repetitive data entry. Some data are standardized, but inconsistent non-standard data and a few Center unique systems still exist.	***Score 1*** Provides no tools for analysis and reporting. Multiple data sources must be analyzed to determine true source. Data must be manually transferred from one organization to another. Separate and unique systems exist throughout the agency. These systems include multiple sets of data and require redundant data entry.
2. Achieve Efficiencies & Operate Effectively	***Score 3*** To meet this driver, an alternative should provide tools, processes, or opportunities for significant improvement in the quality of customer service (or cost savings) and allows for value added services, given the downsized workforce and reduced budget.	***Score 2*** Offers some improvement in the number or types of services provided and in the quality of customer service. Offers some potential for cost savings.	***Score 1*** Provides the minimum level of compliance with legal obligations, and provides minimal services and standards of service.
3. Exchange Information with Customers & Stakeholders	***Score 3*** Provides an integrated and consolidated information source to facilitate sharing accurate and real-time information with customers. In order for an alternative to fully meet this driver the system will also use e-commerce strategies to disseminate and share information and customers will be able to directly access appropriate information from their desktop.	***Score 2*** Provides a somewhat integrated or consolidated information source. The system may take advantage of some e-commerce strategies. Customers can access some information from their desktop.	***Score 1*** Provides no consolidated or integrated information source and uses no e-commerce strategies.

Exhibit 6-5: Sample Non Quantifiable (Qualitative) Benefit Scoring Definitions

Caveats & limitations

Overestimating benefits can lead to a sub-optimal investment decision. A sensitivity analysis should be conducted to provide insight into the probability of the benefit being realized as well as when it will be realized.

7 Special Studies/ Analyses

In the previous sections of this document, the building blocks (i.e., the LCC methodology, the financial analysis techniques, and the benefits analysis and assessment methods) needed to conduct Special Studies and Analyses[11] were presented. This section describes several specific types of studies that are frequently requested and are of particular importance to NASA. This section also discusses learning curves, labor rates, and the use of accounting data in the analysis process.

7.1 Lease Versus Buy Analysis

A lease[12] versus buy analysis can be performed once the decision is made to acquire an asset. While the process of buying an asset is obvious, the analysis behind the decision to lease is not.

When analyzing the financial considerations under the lease versus buy decision process, one needs to consider the LCC of either leasing or buying and operating and maintaining the hardware. The most meaningful financial comparison is the cost of lease financing versus the cost of debt financing. While comparing absolute LCC is important, it is equally critical to take into consideration fiscal budgetary constraints. While the LCC of leasing may be higher over the entire term the hardware is leased, the annual expenditures may fit better with NASA's budgetary limitations. However, the lease versus buy decision cannot be based purely on financial data or budgetary considerations. The decision must be made on a best value consideration. A best value or best selection analysis (see Section 7.4 for more detail) would introduce intangible benefits that could be benefits of either leasing or buying.

There are many non-financial factors to consider when making the decision to lease or buy:

- Asset redeployment/disposal
- Asset tracking
- Cancellation options are valuable
- Convenience
- Ease of contracting
- Maintenance is provided
- Political considerations
- Shortened product life cycle
- Technology refresh
- Transference of residual risk

Traditionally, factors such as asset tracking and asset redeployment/disposal are considered to be advantages of leasing, however, circumstances could exist which would make these factors a disadvantage. Similarly, these types of benefits could be provided through certain procurement vehicles. It is critical to be aware of all competing purchase alternatives to leasing as well as being aware of the legislative and policy directives guiding leasing.

[11] For the purposes of this document, a Special Study is defined as a discrete or selective study required to determine whether the measures of calculation and effectiveness are adequate to the distinguishing of alternatives.

[12] A lease is a long-term agreement between a user (lessee) and the owner of an asset (lessor) where periodic payments are made by the lessee in exchange for most of the benefits of ownership. A lease is comparable to a loan in the sense that lessee is required to make a specified series of payments and that failure to meet these payments could result in loss of the asset.

For example — **GAO Navy Ship Leasing Study**

On June 25, 1999 the United States General Accounting Office (GAO) released testimony on the "Historical Insights into Navy Ship Leasing". (The full text can be found at http://www.gao.gov/archive/1999/ns99125.pdf.) This study details the basis and support for the U.S. Navy lease versus buy decision process, the concerns surrounding those decision, and the subsequent changes in the law that have directly affected current lease versus buy decisions. In the 1970s and 1980s, the U.S. Navy entered into several long-term leasing agreements with numerous contractors to acquire its combat ships. The primary reason for leasing was attributed to the fact that leasing arrangements allowed the Navy to acquire the ships without a large, up-front obligation of procurement funds. However, those leasing decision were based on analyses that were influenced by the methodologies and assumptions used in the analyses regarding the tax revenues, residual values, and discount rates. Those methodologies and assumptions ultimately made leasing cheaper, but the GAO study shows that if the Navy's analyses had used assumptions that more accurately reflected the Government's total costs, they would have concluded that buying was the more cost effective decision. Since then many legislative changes have been implemented to provide Government agencies with more detailed guidelines for performing lease versus buy comparisons.

For more information

Office of Management and Budget (OMB) Circular A-94, Chapter 13 and Appendix C (http://www.whitehouse.gov/omb/circulars/a094/a094.html)

OMB Circular A-11, Appendix B (http://www.whitehouse.gov/omb/circulars/a11/2001_A-11.pdf)

NPG Directive 210-PG-5100.1.1 (http://msc-docsrv.gsfc.nasa.gov/GDMS_docs/Pgwi200/210-PG-5100.1.1-.pdf)

7.2 Cost Performance/Schedule Trade Studies

Cost performance/schedule trade studies are a systematic, interdisciplinary examination of the factors affecting the cost of a system to find methods for meeting system requirements at an acceptable cost. These studies are accomplished by analyzing numerous system concepts to find ways to attain necessary performance while balancing essential requirements that must be satisfied for the system to be successful. The objective of the cost performance trade study is not to minimize the cost of the system, but to achieve a specified level of cost reduction established by the target costing system (see Exhibit 7-1).

Cost estimates are key inputs during trade studies, used to determine the most realistic and cost effective mission architectures and system designs.

Target Costing and Value Engineering

Many Federal agencies have implemented principles that embody an old idea: buying only what you can afford and trading off some capabilities to reduce overall cost. Target costing and value engineering have been coupled over the past several years in support of initiatives to reduce the LCC of systems.

These Federal Agencies have initiatives that require setting aggressive, but realistic, cost objectives when defining the operational requirements of a system. Effective cost management must start at the beginning of a system or product lifecycle. Once a system is designed, most of the costs that will be incurred in building and operating the system have already been committed.

- Target costing is a structured approach to determine the cost at which a system or product with specified performance and reliability must be produced to shift the decision point toward proceeding with the project.
- Value engineering is used in the product design stage to find ways to achieve the specified performance at the required level of performance

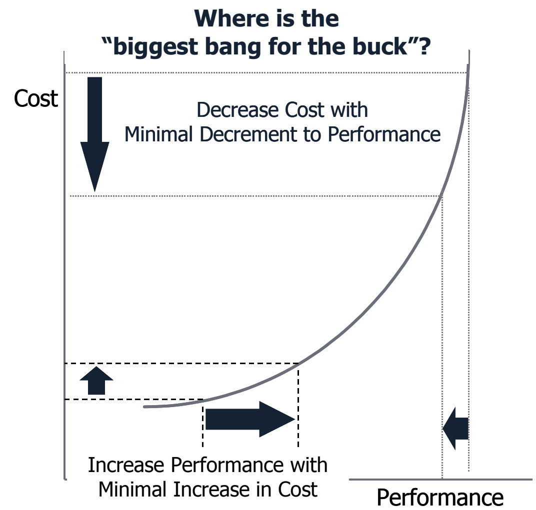

Exhibit 7-1: Cost versus Performance

The objective of a trade study is to obtain the merit of the worth (in a single figure) of each candidate and to select the one having the greatest relative value. The following steps provide a general framework to assist NASA's CEC prepare a trade study.

1. Define the Purpose
2. State the Problem
3. Describe the Selection Scheme and Criteria Used
4. Identify the Design Approaches/Characteristics
5. Conduct a Coarse Screening
6. Determine the Preferred Approach
7. Formulate Recommendation(s)

The detail or depth of the definition of the design approaches will depend on the resources available and should remain consistent throughout the trade study. To determine the preferred approach, the estimator must performing analyses (including cost) to evaluate the capability of each candidate's concept to satisfy selected criteria and comparing the results. The actual selection of the preferred approach is determined by applying the evaluation criteria to each candidate to identify which has the greatest potential to benefit to the program. For additional information on cost performance/schedule trade studies, refer to Appendix R for the Trade Study Preparation Guide.

Tips

Executing a Trade Study

- The selection scheme and criteria used should be comprehensive enough to guide the selection of the best alternative(s).
- Only reasonable and attainable design approaches should be considered in the identification of design approaches and characteristics.

7.3 Software Estimation

Software represents a substantial portion of the cost for space systems. NASA's CEC, in their efforts to improve cost estimating accuracy and reliability, must focus their efforts on managing software cost estimates to ensure they are realistic and complete.

Estimating the cost, schedule, and effort associated with a proposed software development project is a critical and challenging task. The software development industry, as a whole, does not have a good track record when it comes to completing a project on time and within budget. Recent studies have shown that only 25 percent of software development projects are completed successfully within the estimated schedule and budget.[13] This statistic has shown no significant improvement over the past decade. Initial project estimates are typically overly optimistic and inaccurate, underscoring the criticality of developing robust and thorough estimates early in a project's development life cycle.

7.3.1 Estimation Methods

Although many methodologies can be applied to generate software estimates, they can typically be categorized into two groups: manual and tool-driven. Both types are appropriate in different situations, and each has advantages and disadvantages. It is also common to apply more than one method to produce multiple estimates for a development project, then to reconcile the differences.

7.3.1.1 Manual Estimation

Manual software estimation typically uses a straightforward methodology to derive effort, cost, and schedule. This includes analogy, engineering buildup, or CER factors. Analogy compares the project at hand to "comparable" projects. The estimate then may be adjusted to account for any obvious differences (e.g., estimated size or complexity). Engineering buildup leverages expertise of people who have experience in software development. These experts apply their best judgment to estimate the duration and effort required to complete the project. The analysis may be broken down into work packages, modules, or activities to drive to greater granularity and accuracy. CERs, or "rules of thumb," use simple factors such as productivity metrics, percentages, or multipliers that are easily applied to size, staffing, or other estimate data to derive cost, effort, and schedule.

The main advantage of manual estimation is the ability to produce one quickly and the simplicity with which one can be completed. While these methods are practiced widely, they are most appropriate for estimates very early in the project life cycle, very small development efforts, or non-critical, unimportant projects. The results of manual methods are also useful as cross-check estimates. However, for mission critical applications, larger development efforts, and contracted software development projects,[14] the accuracy of manual methods has not proven sufficient. Manual methods simply cannot account for the complexity of factors that affect the outcome of software development projects.

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13 *1998 Standish Group CHAOS Report.*

14 *Jones, T. Capers (1998). Estimating Software Costs. Washington, D.C.: McGraw-Hill. p. 173.*

7.3.1.2 Tool-Driven Estimation

Software development cost estimating tools generally can produce more thorough and reliable estimates than manual methods. These parametric tools are based on data collected from hundreds of actual projects. The algorithms that drive them are derived from the numerous inputs to the models from personnel capabilities and experience and development environment to amount of code reuse and programming language. These tools usually provide default settings for these input parameters, which means that a reasonable estimate can be derived from a minimal amount of data. Additionally, these parametric tools provide flexibility by accepting multiple sizing metrics, so estimators can apply any number of sizing methodologies. Software cost models produce even better results when calibrated to specific development teams using actual project data. Another significant benefit of automated tools is the ability to perform sensitivity and risk analysis for a project estimate. Estimators can manipulate various inputs to gauge the overall sensitivity to parameter assumptions and then assess the overall project risk based on the certainty of those inputs.

The main drawback to software cost estimating tools is the cost and the need for users to be trained. Some tools are expensive and complex. Many commercial software estimation tools are available on the market. Currently, NASA has agency-wide licenses for both PRICE and SEER estimating suites, which both include software estimation tools. These two specific tools trend toward the higher side of the cost-complexity spectrum, but there are several other models available to estimate software costs. Please see Appendix K for more information.

7.3.2 Sizing Methods

Size is the most important cost driver of software development, yet it still remains a fairly common source of error in software cost estimation. Software sizing is the process of determining how big the application being developed will be.[15]

Not only is it often difficult to generate a size estimate for an application that has not yet been developed, the software process often experiences requirements growth and scope creep that can significantly impact cost estimates. Projects that do not track and control this trend typically have difficulty dealing with budget and schedule constraints. There are two sizing methods that are commonly accepted: source lines of code (SLOC) and function point analysis.

7.3.2.1 Source Lines of Code (SLOC)

Counting or estimating SLOC is the most used method of software sizing. This metric looks at the volume of code required to develop the software. Sizing is accomplished through analogy, engineering expertise, or automated code counters. While SLOC is the most common sizing method, it presents some difficulties as a common metric because there is no standard to define what should be counted as a line of code and what should not. Typically estimators consider either physical implementation or logical statements when counting SLOC. In some programming languages, physical lines and logical statements are nearly the same, but in others, significant differences in size estimates can result. Because each line is terminated by the enter key, the physical SLOC metric is very simple to count and lends itself to automated counting tools.[16] Logical statements may encompass several physical lines and typically include executable statements, declarations, and compiler directives. SLOC counts based on logical

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15 *Park, Robert E., Software Size Measurement: A Framework for Counting Source Statements (by Robert E. Park)* *http://www.sei.cmu.edu/pub/documents/92.reports/pdf/tr20.92.pdf*

16 *Jones, T. Capers (1998), p. 319.*

statements usually ignore programmer comments. Organizations, however, may define their own SLOC metrics, which make it especially important to understand that definition early in the estimating process.[17]

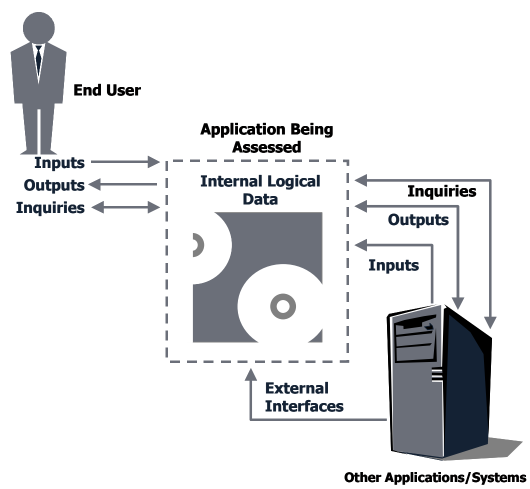
Exhibit 7-2 lists other advantages and disadvantages to the SLOC method.

Advantages	Disadvantages
Relatively easy to come up with a number.	No universal standards create inconsistent estimates; local standards often conflict with each other.
Plenty of historical data available.	Cross-language size estimates are unreliable.
Sometimes automated counting tools can be applied.	Measures components, not completed products.
Supported by most cost estimating tools.	Metrics can be difficult to interpret (productivity paradox).[18]
Numerous write-ups on how to estimate using the SLOC approach (including authors such as Barry Boehm and Capers Jones).	Irrelevant to some modern programming environments (visual languages or code generators).

Exhibit 7-2: SLOC Advantages and Disadvantages

7.3.2.2 Function Point Analysis

The other primary technique for estimating software size is function point analysis. Function points were established in the late 1970s as an alternative to SLOC, but only recently have they gained more attention and use. Function points measure software size based on the functionality requested by and provided to the end user. Functions are categorized as data or transactions. Data functions include logical data groups that are captured and stored by the application being estimated and external data referenced by the application. Transaction functions encompass inputs (add, change, and delete), outputs (reports), and inquiries (searches or retrievals).



One of the key benefits of using function points as the sizing method is that counting standards are established and maintained for the technique. The International Function Point Users Group (IFPUG)[19] manages, regulates, and issues updates to these standards, which make function points fully documentable and traceable. Many resources can avail themselves to function point analysis at various stages in the development life cycle, including user or estimator interviews,

[17] *For a comprehensive definition checklist for SLOC counts, refer to: Boehm, Barry W. Software Cost Estimation with COCOMO II. Upper Saddle River, NJ: Prentice Hall PTR. pp. 77-82.*

[18] *The productivity paradox is a phenomenon where the programming language that seems to have the best productivity metrics (e.g., effort per SLOC), actually results in the highest total cost because the language is less efficient than other, more modern programming languages.*

[19] *For more information on function points visit www.ifpug.org.*

requirements and design documents, data dictionaries and data models, use cases and user guides, and even screen captures or the actual software. Function points, like SLOC, offer certain advantages and disadvantages, which are detailed in Exhibit 7-3.

Advantages	Disadvantages
Standards are established and reviewed frequently.	Largely a manual process.
Resulting metrics are logical and straightforward.	Accurate counting requires in-depth knowledge of standards.
Counting resources are available from requirements stage and applicable for full life-cycle analysis.	Some variations exist that are not standardized (Mark II, 3D, full, feature points, object points, etc.).
Technology, platform, and language independent.	Not as much historical data available as SLOC.
Objectively defines software application from the user's perspective.	Sometimes derived from SLOC counts (called backfiring), which can be inaccurate and misleading.

Exhibit 7-3: Function Point Advantages and Disadvantages

7.4 Best Value Selection

Best Value Selection (BVS) is most commonly used in proposal evaluations. BVS seeks to select a bid based on the best combination of price and qualitative merit of the offeror's submission, thus reducing the administrative burden on the offerors and the Government. BVS takes advantage of the lower complexity of mid-range procurements and predefines the value characteristics that will serve as discriminators among offers submitted.

BVS evaluation is based on the premise that, if all bids are of approximately equal qualitative merit, award will be made to the offeror with the lowest evaluated price. The Government will consider awarding to an offeror with the lowest evaluated price. The Government will consider awarding to an offeror with higher qualitative merit if the difference in price is commensurate with added value. Conversely, the Government will consider making award to an offeror whose offer had lower qualitative merit if the price differential between it and other offers warrants doing so. The Government may award the contract to the offeror providing the best overall value.

When the life cycle benefits of investment alternatives do not differ significantly between each other and each alternative satisfies a given set of requirements, then a best value judgment can be made. This involves determining which of several alternatives has the lowest cost providing the highest value.

? How is it calculated

Costs are calculated using present value and discounting techniques discussed in Section 5.1.1. Using these techniques, the most cost-effective alternative is preferred because it provides the same benefits at a lower cost.

7.5 Real Options Approach

The real options approach is a financial technique for valuing investment alternatives. This approach is primarily a decision tool that indicates whether or not to proceed with an investment after pre-established decision points are reached. This approach is more suited to large scale, multi-year acquisition projects where NASA would need to decide whether to continue spending or abandon a specific project.

How is it calculated

Real Options Value

There is no single formula for calculating the real options value. Instead, this approach integrates NPV techniques with a decision-tree framework to determine the whether a project should proceed or be terminated.

For more information

Numerous books and articles have been published on real options topics, including:

Avinash Dixit and Robert Pindyck. Investment Under Uncertainty. Princeton University Press, Princeton, NJ (1994).

Lenos Trigeorgis. Real Options; Managerial Flexibility and Strategy in Resource Allocation. MIT Press, Cambridge, MA (1999).

Martha Amram and Nalin Kulatilaka. Real Options: Managing Strategic Investments in an Uncertain World. Harvard Business School, Boston, MA (1999).

Cumulative Average Curve

Calculates average unit value of production lot

$Y = AX^b$

- Y = Cum average unit value of the Xth unit
- A = Theoretical first unit value (T1)
- X = Unit number
- b = Log(slope) / Log (2)

Midpoint Value

Point on the curve where the unit value represents the simple average of all units in the lot

$$MPV = \left[\frac{(X_e - X_b + 1) * (1 + b)}{(X_e + 0.5)^{1+b} - (X_b - 0.5)^{1+b}} \right]^{-1/b}$$

- MPV = True lot midpoint value
- X_e = End point (last unit in the lot)
- X_b = Beginning point (first unit in lot)
- b = log(slope) / log(2)

Unit Curve

Calculates unit value of specific point on curve

$Y = AX^b$

- Y = Unit value of the Xth unit
- A = Theoretical first unit value (T1)
- X = Unit number
- b = log(slope) / log(2)

Rules of Thumb

Slope by Industry:

- Aerospace 85%
- Complex machine tools 75-85%
- Electronics manufacturing 90-95%
- Machining or punch press 90-95%
- Repetitive electrical operations 75-85%
- Repetitive welding operations 90%
- Raw materials 93-96%
- Purchased parts 85-88%

All percentages listed above were taken from the Cost Estimator's Reference Manual.

Approximation/Arithmetic Mean Approach:

Shortcut to calculating the midpoint

- For the first lot:
  - If the lot size < 10
    MPV = lot size / 2 + (# of prior units)
  - If the lot size > 10
    MPV = lot size / 3 + (# of prior units)
  - For subsequent lots:
    MPV = lot size / 2 + (# of prior units)

Learning curves, sometimes referred to as improvement curves or progress functions, are based on the concept that resources required to produce each additional unit decline as the total number of units produced increases. The term learning curve is used when referring to an individual's performance. If the analysis involves all the components of an organization, it is referred to as a progress function or an improvement curve.

The learning curve concept is used primarily for uninterrupted manufacturing and assembly tasks, which are highly repetitive and labor intensive. The major premise of learning curves is that each time the product quantity doubles the resources (labor hours) required to produce the product will reduce by a determined percentage of the prior quantity resource requirements. This percentage is referred to as the curve slope. Simply stated, if the curve slope is 90% and it takes 100 hours to produce the first unit then it will take 90 hours to produce the second unit. As the quantity doubles (from 1 to 2) the resource requirement reduces from 100 to 90 (100 * 90%).

The two types of learning curve approaches are unit curve and cumulative average curve. The main difference between the two approaches is, as indicated by their names, the cumulative average curve calculates the average unit value for the entire curve to a set point while the unit curve calculates the unit value for a specific quantity point. Over the first few units, an operation following the cumulative average curve will experience a much greater reduction in cost than an operation following a unit curve with the same slope. This difference decreases as the quantity increases.

Learning curve analysis is primarily used in situations that provide an opportunity for improvement or reduction in labor hours per unit. The examples below illustrate some circumstances where it is appropriate to use learning curves:

- High proportion of manual labor,
- Uninterrupted production,
- Production of complex items,
- No major technological change, and
- Continuous pressure to improve.

For more information — Learning Curves

For more information on learning curves please see the following websites:

Learning Curve Calculator	http://www.jsc.nasa.gov/bu2/learn.html
Article on The Learning Curve	http://www.computerworld.com/cwi/story/0,1199,NAV47-68-85-1942_STO61762,00.html
Department of Energy Office of Science Article on Learning Curves	http://www.sc.doe.gov/sc-80/sc-82/430-1/430-1-chp21.pdf
University of Michigan Article on Learning Curves	http://ioe.engin.umich.edu/ioe463/learning.pdf

7.7 Labor Rates

Labor Rates are used along with hours to estimate the total cost of labor dollars that will be expended on a project. The evaluation of rates, hours, and accompanying assorted skill mixes is important because of the significant contribution to total program/project costs. This is especially true with labor-intensive projects, as opposed to hardware intensive programs. The largest impact in the labor area will be the inclusion of civil service labor charges in program/project estimates. As NASA moves to the full cost concept, particular attention must be paid to the inclusion of civil service labor in all cost estimates, which is just as important as including contractor labor costs.

Labor rate analysis and estimating can take on many different forms. Historical rates can be used as a starting point to escalate to future rates. Additionally, Office of Personnel Management Salary Tables can be used to obtain current civil service rates as the basis of estimates. After obtaining the basic civil service rates the cost estimator needs to estimate and develop Leave and Fringe Benefit (L&FB) rates to include in the estimate. L&FB includes cost elements such as:

- Contributions to Retirement Plans:
  - Civil Service Retirement System (CSRS)
  - Federal Employees Retirement System (FERS),
- Health Insurance Tax (HIT),
- Health & Life Insurance Premiums,
- Workman's Compensation,
- Thrift Savings Plan (TSP) Matching Contributions, and
- Leave and Paid Holidays.

Extracted from the NASA Full Cost Implementation Guide, located at http://ifmp.nasa.gov/codeb/library/fcimplementation.pdf, Exhibit 7-4 demonstrates the development of an L&FB rate for one fiscal year. It was assumed for this example that 40% of the workforce are covered by CSRS and 60% by FERS and that the Government's contributions to those plans is 9% and 19% (which includes Social Security taxes), respectively.

For example — **Leave & Fringe Benefit Rate**

LEAVE AND FRINGE BENEFIT RATE

Example

		$000
Retirement (Including HIT)		
CSRS	9% of salaries (40% of workforce)	4680
FERS	19% of salaries (60% of workforce)	14820
Health & Life Insurance		5500
Thrift Savings Plan		2500
Workman's Compensation		500
Leave and Paid Holidays		19500
Total Leave and Benefits		47500
Total Estimated Salaries Less Leave		110,500
Rate		43%

Figure 10

ALLOCATION OF L&FB TO COST CATEGOGIES

Example

	Salaries	L&FB Rate	Allocate L&FB
Direct Projects	77000	43%	33100
Service Activities	19250	43%	8275
G&A	14250	43%	6125
Total	110,500		47,500

Exhibit 7-4: Leave and Fringe Benefits Example

7.8 Full Cost Accounting

Full cost management, budgeting, and accounting will have significant impacts upon project/program cost estimating. The NASA Full Cost Initiative Agencywide Implementation Guide (http://ifmp.nasa.gov/codeb/library/fcimplementation.pdf) includes policy and practice improvements in those three areas and is anticipated to provide complete cost information for more fully informed decision making.

The concept of full cost will tie all Agency costs (including civil service personnel costs) to major activities. All costs will be associated with an activity and, as a result, referred to as a cost object. In the past, civil service personnel costs and certain other costs of the institution were not tied to projects. However, that has changed and now they will be charged or allocated. Cost estimators and proposal evaluators should be highly conscious of the need to include these costs in project/program estimates and must also conduct adequate reviews of proposals to ensure that they include these costs.

Costs may be categorized in different ways. NASA's full cost approach separates costs into three categories:

1. **Direct Costs –** Direct costs are costs that are obviously and physically related to a project at the time they are incurred and are subject to influence of the project manager. Examples of direct costs include contractor-supplied hardware and project labor, whether provided by civil service or contractor employees.
2. **Service Costs –** Service costs are costs that cannot be specifically and immediately identified to a project, but can subsequently be traced or linked to a project and are assigned based on usage or consumption. Examples of services costs include automatic data processing and fabrication.
3. **General and Administrative (G&A) Costs –** G&A costs are costs that cannot be related or traced to a specific project, but benefit all activities. Such costs are allocated to a project based on a reasonable, consistent basis. Examples of G&A costs include costs associated with financial management, procurement, security, and legal activities.[20]

The full cost of a project is the sum of all direct costs, service costs, and G&A costs associated with the project. Because service and G&A costs cannot be immediately and directly identified with a specific project, service activity costs and G&A cost pools are used to accumulate costs of similar purpose. Using previous years' rates and future rate projections from these cost pools, the estimator can derive cost estimates to be included in his/her future cost projections.

When preparing project/program estimates, the estimator can also obtain historical costs for similar projects and use these in developing his/her estimates. The historical information can provide a good indicator of the accuracy of the cost estimate under development. As shown in Exhibit 7-5, the full cost accounting model is taken from the NASA Full Cost Initiative Agencywide Implementation Guide. The estimator can use this illustration as a guide to focus his/her cost estimating techniques to ensure that all costs are included in the projection.

[20] *NASA Full Cost Initiative Agencywide Implementation Guide, February 1999.*

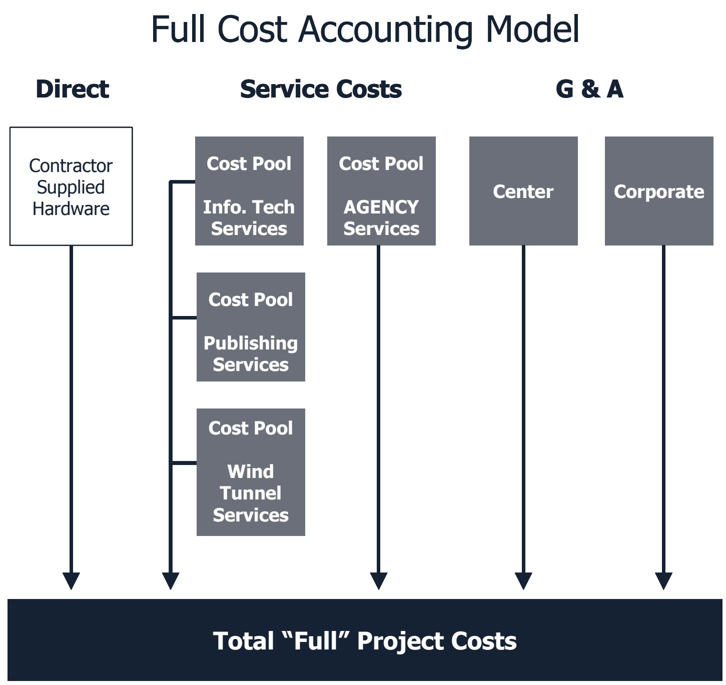


Exhibit 7-5: Full Cost Accounting Model

7.8.1 NASA Wrap Rates

NASA wrap rates or additional costs can be defined as those additional service pools (charges) that should be included in project/program estimates because they are a part of doing business from which projects/programs receive benefit. Examples (not all inclusive) of these service charges or additional costs can include such items as:

- System engineering
- Project management
- Workstation maintenance
- Application programming
- Computer usage
- Facilities
- Fabrication

Because each NASA Center offers different skills and competencies, they will have different service pool structures. The cost estimator should be careful to include estimated charges from all pools across the NASA Agency to make the cost estimates more realistic.

Appendices

A. Acronym List

In addition to the following list of defined acronyms, other useful cost terms can be found on the following websites:

Acronym Finder	http://www.acronymfinder.com/
Cost Estimating Acronym Glossary	http://www.jsc.nasa.gov/bu2/acronyms.html
Java EOSDIS Acronym Finder	http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/MODIS/documentation/eosdis_acronym.shtml
NASA Acronym List (GSFC)	http://library.gsfc.nasa.gov/Databases/Acronym/acronym.html
NASA Acronym List (KSC)	http://www.ksc.nasa.gov/facts/acronyms.html
NASA Acronym List (MSFC)	http://liftoff.msfc.nasa.gov/help/acronym.html
NASA Earth Science Acronyms	http://gcmd.gsfc.nasa.gov/Aboutus/sitemap.html
WorldWide Web Acronym and Abbreviation Server	http://www.ucc.ie/acronyms/

AACE	Association for the Advancement of Cost Engineering
AATe	Architectural Assessment Tool - Enhanced
ACE	Advocacy Cost Estimate
ACEIT	Automated Cost Estimating Integrated Tools
AFIT	Air Force Institute of Technology
AFSC	Air Force Space Command
AFSMC	Air Force Space and Missile Systems Center
AHP	Analytic Hierarchy Process
ALMC	Army Logistics Management College
AMCM	Advanced Missions Cost Model
ANP	Analytic Network Process
AO	Announcement of Opportunity
AoA	Analysis of Alternatives
AGE	Aerospace Ground Equipment
APA	Allowance for Program Adjustment
ARC	Ames Research Center
ASPE	American Society of Professional Estimators
ATP	Authorization to Proceed
BCA	Business Case Analysis
BCR	Benefit/Cost Ratio
BVS	Best Value Selection
BMO	Business Management Office
BY	Base Year
C/SCSC	Cost/Schedule Control System Criteria
C/SSR	Cost/Schedule Status Report

CAICAT	Composites Affordability Initiative Cost Analysis Tool
CAIG	Cost Analysis Improvement Group
CAO	Cost Analysis Office
CARD	Cost Analysis Requirements Description
CASA	Cost Analysis Strategy Assessment
CBA	Cost Benefit Analysis
CCDR	Contractor Cost Data Reporting
CEA	Cost Estimation and Analysis
CEC	Cost Estimating Community
CEH	Cost Estimating Handbook
CER	Cost Estimating Relationship
CES	Cost Element Structure
CEWG	Cost Estimating Working Group
CFO	Chief Financial Officer
CFSR	Contract Funds Status Report
CLIN	Contract Line Item Number
COCOMO	Constructive Cost Model
COMET	Conceptual Operations Manpower Estimating Tool
CONOPS	Concept of Operations
COSMIC	Computer Software Management Information Center
CoSTER	Consortium on Space Technology Estimating Research
COTS	Commercial-off-the-Shelf
CPI	Consumer Price Index
CSRS	Civil Service Retirement System
CY	Constant Year
CY	Current Year
DACS	Data and Analysis Center for Software
DAU	Defense Acquisition University
DCF	Discounted Cash Flow
DDT&E	Design, Development, Test & Evaluation
DFRC	Dryden Flight Research Center
DoD	Department of Defense
DSMC	Defense Systems Management College
DSN	Deep Space Network
EA	Economic Analysis
EAC	Estimate at Completion
EADP	Economic Analysis Development Plan
ECHO	Environmental Costs of Hazardous Operations
ECI	Employment Cost Index
ECOM	ESA Cost Modelling Software
ECOS	ESA Costing Software
EMP / EMI	Electromagnetic Pulse / Electromagnetic Interference
EOSDIS	Earth Observing Station Data & Information System
EQEA	Environmental Quality Economic Analyses

ESA	European Space Agency
EVM	Earned Value Management
EVMS	Earned Value Management System
FACGSE	Spaceport Facility and GSE Acquisition Cost Estimator
FAI	Federal Acquisition Institute
FAIR	Federal Activities Reform
FAR	Federal Acquisition Regulation
FEA	Functional Economic Analysis
FERS	Federal Employees Retirement System
FFP	Firm Fixed Price
FH	Flight Hardware
FPA	Function Point Analysis
FRISK	Formal Risk Assessment of System Cost Estimates
FV	Future Value
FY	Fiscal Year
G&A	General and Administrative
GAO	General Accounting Office
GDP	Gross Domestic Product
GOTS	Government-off-the-Shelf
GPRA	Government Performance and Results Act
GR&A	Ground Rules and Assumptions
GRC	Glenn Research Center
GSE	Government Support Equipment
GSFC	Goddard Space Flight Center
HIT	Health Insurance Tax
HQ	Headquarters
HSF	Human Space Flight
HW	Hardware
IA	Independent Assessment
IAF	International Astronautics Federation
IAR	Independent Annual Review
ICE	Independent Cost Estimate
IFPUG	International Function Point Users Group
ILCCE	Independent Life Cycle Cost Estimate
IMLEO	Initial Mass in Low-Earth Orbit
IOC	Initial Operating Capability
IPAO	Independent Program Assessment Office
IPI	International Price Index
IPR	Initial Program Review
IPT	Integrated Product Team
IRM	Information Resource Management
IRR	Internal Rate of Return
IRS	Internal Revenue Service
ISE	Intelligent Synthesis Environment

ISO	International Standards Organization
ISPA	International Society of Parametric Analysts
IT	Information Technology
ITMRA	Information Technology Management Reform Acquisition
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
KSC	Kennedy Space Center
L&FB	Leave and Fringe Benefits
LaRC	Langley Research Center
LCC	Life-Cycle Cost
LCCE	Life Cycle Cost Estimate
LOOS	Launch and Orbital Operations Support
MAIS	Major Automated Information Systems
MDAPS	Major Defense Acquisition Programs
MCC	Mission Control Center
MESSOC	Model for Estimating Space Station Operations Costs
MICM	Multi-Variable Instrument Cost Model
MIL-STD	Military Standard
MPV	Mid-Point Value
MS	Microsoft
MSFC	Marshall Space Flight Center
MSI&T	Mission System Integration and Test
N/R	Not Relevant
NAFCOM	NASA/Air Force Cost Model
NAR	Non-Advocate Review
NASA	National Aeronautics and Space Administration
NCCA	Naval Center for Cost Analysis
NCMA	National Contract Management Association
NDI	Non-Developmental Item
NODIS	NASA On-line Directives Information System
NPD	NASA Policy Directive
NPG	NASA Procedures and Guidelines
NPV	Net Present Value
N/R	Not Relevant
NRA	NASA Research Announcement
NWODB	New Ways of Doing Business
O&M	Operating and Maintenance
O&S	Operations and Support
OCM	Operations Cost Model
OLS	Ordinary Least Squares
OMB	Office of Management and Budget
PCA	Program Commitment Agreement
PCC	Program Cost Commitment
PDR	Preliminary Design Review

PM	Program / Project Manager
PMA	President's Management Agenda
PMC	Program Management Council
PMI	Project Management Institute
POE	Program Office Estimate
POP	Program Operating Plan
PPI	Producer Price Index
PRICE	Parametric Review of Information for Cost and Evaluation
PRICE H	PRICE Hardware
PRICE HL	PRICE Hardware Life Cycle
PRICE M	PRICE Microcircuits
PRICE S	PRICE Software
PV	Present Value
PWD	Procurement Work Directive
QFD	Quality Function Deployment
R & D	Research and Development
RDT&E	Research, Development, Test, and Evaluation
REVIC	Revised Intermediate COCOMO
RFP	Request for Proposal
ROI	Return on Investment
RMO	Resource Management Office
ROM	Rough Order of Magnitude
RSS	Residual Sum of Squares
RY	Real Year
SCEA	Society of Cost Estimating and Economic Analysis
SCT	Software Costing Tool
SEER	System Evaluation & Estimation of Resources
SEER-DFM	SEER Design for Manufacturability
SEER-H	SEER Hardware Estimation and Life Cycle Cost Analysis
SEER-IC	SEER Custom Integrated Circuit Development
SEER-SEM	SEER Software Estimation Model
SEER-SSM	SEER Software Sizing Model
SICM	Scientific Instrument Cost Model
SIR	Savings to Investment Ratio
SLOC	Source Lines of Code
SMAD	Space Mission Design and Analysis
SME	Subject Matter Expert
SMO	Systems Management Office
SOCM	Space Operations Cost Model
SRA	Society for Risk Analysis
SSA	Social Security Administration
SSC	Stennis Space Center
SSCM	Small Satellite Cost Model
SVLCM	Spacecraft/Vehicle Level Cost Model

SW	Software
T&M	Time and Materials
T1	Theoretical First Unit Value
TBD	To Be Determined
TCO	Total Cost of Ownership
TCOR	Total Cost of Ownership Reduction
TDRSS	Tracking and Data Relay Satellite System
TIMS	Tactical Information Management System
TOA	Total Obligation Authority
TOR	Terms of Reference
TRL	Target Requirement List
TSP	Thrift Savings Plan
TSS	Total Sum of Squares
TY	Then Year
USC	United States Code
USCM	Unmanned Spacecraft Cost Model
USSGL	United States Government Standard General Ledger
WBS	Work Breakdown Structure

B. Glossary

In addition to the following defined terms, other useful cost terms can be found on the following websites:

Acronym Finder	http://www.acronymfinder.com/
Cost Estimating Acronym Glossary	http://www.jsc.nasa.gov/bu2/acronyms.html
Java EOSDIS Acronym Finder	http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/MODIS/documentation/eosdis_acronym.shtml
NASA Acronym List (GSFC)	http://library.gsfc.nasa.gov/Databases/Acronym/acronym.html
NASA Acronym List (KSC)	http://www.ksc.nasa.gov/facts/acronyms.html
NASA Acronym List (MSFC)	http://liftoff.msfc.nasa.gov/help/acronym.html
NASA Earth Science Acronyms	http://gcmd.gsfc.nasa.gov/Aboutus/sitemap.html
WorldWideWeb Acronym and Abbreviation Server	http://www.ucc.ie/acronyms/

@RISK®: Risk Analysis and Simulation add-in for Microsoft Excel® or Lotus® 1-2-3. @RISK uses Monte Carlo simulation that allows taking all possible outcomes into account. Replace uncertain values in the spreadsheet with @RISK functions, which represent a range of possible values. Select bottom-line cells, like Total Profits, as outputs, and start a simulation. @RISK recalculates the spreadsheet, each time selecting random numbers from the @RISK functions entered. The result is distributions of possible outcomes and the probabilities of getting those results. The results illustrate what could happen in a given situation, but also how likely it is that it will happen.

Accounting Estimate: Uses engineering estimates of reliability, maintainability, and component cost characteristics, etc. to build estimates from the "bottom-up" for each cost category.

Acquisition Strategy: The method utilized to design, develop, and display a system through its life cycle. It articulates the broad concepts and objectives, which direct and control the overall development, production, and deployment of a materiel system. It is the framework for planning, directing, contracting for, and managing a program. It provides a master schedule for research, development, test, production, fielding, modification, postproduction management, and other activities essential for program success.

Advocacy Cost Estimate (ACE): Prepared by cost analysts who are a part of the design team and provide the program/project management with an estimated cost based on translating the technical and design parameters characteristics into cost estimates using established cost estimating methodologies.

Analogous System Estimate: With this technique, a currently fielded system (comparable system) similar in design and/or operation of the proposed system is identified. The cost of the proposed system is developed by taking the fielded system's data and adjusting it to account for any differences. Analogous estimates are also called *Comparative* or *Extrapolated* estimates.

Analysis of Alternatives (AoA): Broadly examines multiple elements of project or program alternatives including technical risk and maturity, and costs. AoAs are intended to illuminate the risk, uncertainty, and the relative advantages and disadvantages of the alternatives being considered; show the sensitivity of each alternative to possible changes in key assumptions; and aid decision-makers in judging whether or not any of the proposed alternatives offer sufficient operational and/or economic benefit to be worth the cost.

Analytic Hierarchy Process (AHP): Structures problems into a hierarchical structure in order to reduce complexity. AHP is a feature of Expert Choice.

Analytic Network Process (ANP): Uses non-linear models to demonstrate the relationship between the elements. ANP is a feature of Expert Choice.

Announcement of Opportunity (AO): This is generally used to solicit proposals for unique, high cost research investigation opportunities that typically involve flying experimental hardware provided by the bidder on one of NASA's Earth-orbiting or free-flying space flight missions. Selections through AO's can be for periods of many years, involve budgets of many millions of dollars for the largest programs, and usually are awarded through contracts, even for non-profit organizations, although occasionally grants are also used.

Assumption: A supposition on the current situation, or a presupposition on the future course of events, either or both assumed to be true in the absence of positive proof. Assumptions are necessary in the process of planning, scheduling, estimating, and budgeting.

Base Year (BY): A term used to define a year that is: (1) the economic base for dollar amounts in a proposal estimate, (2) the base for rate calculation or projection, or (3) the starting point for the application of inflation factors.

Benefit to Cost Ratio (BCR): The benefit cost ratio measures the discounted amount of benefits that the project generates for each dollar of cost. Fundamentally, the computation of the benefit/cost ratio is done within the construct of the following formula: Benefits/Cost.

Best Value Selection: Best Value Selection (BVS) is most commonly used in proposal evaluation. BVS seeks to select an offer based on the best combination of price and qualitative merit of the offeror's submission, thus reducing the administrative burden on the offerors and the Government. BVS takes advantage of the lower complexity of mid-range procurements and predefines the value characteristics that will serve as discriminators among offers submitted.

Beta Curve: Developed at JSC in the 1960s; it is used for spreading parametrically derived cost estimates. It is used for R & D type contracts whereby costs build up slowly during the initial phases, and then escalates as the midpoint of the contract approaches. It is commonly known as the normal distribution curve.

Break-Even Analysis: Analysis used to uncover the point when the cumulative value of savings is equal to the cumulative value of investment.

Business Case Analysis (BCA): Economic Analysis type that documents the review of an entire functional process or sub-process, such as the use of alternative launch vehicles, etc. It requires a risk assessment of each alternative solution, requesting a high and low estimate for each cost element and subsequent probability distribution of expected costs.

Coarse Screening: Step 5 of a Trade Study where the number of candidate solutions is reduced (if necessary) by eliminating those candidates unacceptable for delta cost, risk, safety, performance, schedule, or other reasons.

Commercial-Off-The-Shelf (COTS): Commercial items that require no unique government modifications or maintenance over the life cycle of the product to meet the needs of the procuring agency.

Competitive Sourcing Studies (A-76 Studies): Competitive sourcing is a process to determine the most cost effective method of obtaining services that are available in the commercial market. Agency missions may be accomplished through commercial facilities and resources, Government facilities and resources or mixes thereof, depending upon the product, service, type of mission and the equipment required.

Compounding: Process of going from today's values, or present values (PVs), to future values (FVs).

Constant (Base) Year Dollars: This phase is always associated with a base year and reflects the dollar "purchasing power" for that year. An estimate is in constant dollars when prior-year costs are adjusted to reflect the level of prices of the base year, and future costs are estimated without inflation. A cost estimate is expressed in "constant dollars" when the effect of changes in the purchasing power of the dollar (inflation) has been removed.

Constructive Cost Model (COCOMO): A parametric software cost estimating tool developed and described by Dr. Barry Boehm in his book Software Engineering Economics. COCOMO has three standard modes of software development: Organic, Semi-Detached, and Embedded. The Air Force Cost Analysis Agency's REVIC model is based on the original COCOMO model.

Contract Cost Analysis: Contract cost analysis is the traditional method for analyzing a contractor's proposal. It is the analysis of the separate cost elements and profit of (1) an offeror's cost and pricing data and (2) the judgmental factors applied in projecting from the data to the estimated costs. The analyst does this to form an opinion on the degree to which the proposed costs represent what the contract should cost.

Contract Funds Status Report (CFSR): A report normally required on cost or incentive type contracts to inform the buyer of funds used and status of remaining funds.

Contract Line Item Number (CLIN): Items listed in a contract and priced individually. Some may be options.

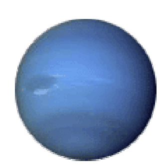
Contract Work Breakdown Structure (WBS): A breakout or subdivision of a project typically down to level three which subdivides the project into all its major hardware, software, and service elements, integrates the customer and contractor effort, provides a framework for the planning, control, and reporting. A WBS applied within a contract.

Contractor Cost Data Report (CCDR): A U.S. Department of Defense report developed to provide contract cost and related data in a standard format.

Contractor Estimate: Title 10 United States Code Section 2306a requires prospective prime contractors and their subcontractors to submit certified cost or pricing data in support of their proposals. They must submit cost data in the SF 1411 format, which requires the contractor to separate the proposal and supporting data into the following groups: Purchased parts, Subcontracted items, Raw material, Engineering labor, Engineering overhead, Manufacturing labor, Manufacturing overhead, Other general and administrative (G&A), and Profit.

Cost Analysis Improvement Group (CAIG): The OSD's Cost Analysis Improvement Group (CAIG) provides an independent cost estimate. The CAIG's independent cost estimates provide useful cost information to DoD decision-makers. The CAIG estimates are intended primarily as internal working documents to ensure that senior officials receive the most candid and complete information about weapons acquisition programs.

Cost Analysis Office (CAO): The Cost Analysis Offices at each NASA Center provide analysis, independent evaluations, and assessments of Center programs/ projects, including programs delegated to the Center as lead center. Some examples of the roles of a CAO are: Serve as the Center's focal point for independent cost estimating and analysis for programs and projects, Support Non Advocate Reviews (NARs), Independent Annual Reviews (IARs), and



Independent Assessments (IAs) of Center programs and projects, and Provide cost analysis expertise to the IPAO to support independent reviews as requested.

Cost Analysis Requirements Description (CARD): The CARD defines, and provides quantitative and qualitative descriptions of, the program characteristics from which cost estimates will be derived. As such, the CARD ensures that cost projections developed by the program/project offices and the independent review organizations are based on a common definition of the system and program.

Cost Benefit Analysis (CBA): An analytic technique that compares the costs and benefits of investments, programs, or policy actions in order to determine which alternative or alternatives maximize net profits. Net benefits of an alternative are determined by subtracting the present value of costs from the present value of benefits. CBA is comprised of 8 steps: analysis of the current environment, perform gap analysis, identify alternatives, estimate costs, perform sensitivity analysis, characterize and value benefits, determine net value of each alternative, and perform risk analysis.

Cost Driver: Those input variables that will have a significant effect on the final cost.

Cost Element Structure (CES): A unit of costs to perform a task or to acquire an item. The cost estimated may be a single value or a range of values.

Cost Estimate: The estimation of a project's life cycle costs, time-phased by fiscal year, based on the description of a project or system's technical, programmatic, and operational parameters. A cost estimate may also include related analyses such as cost-risk analyses, cost-benefit analyses, schedule analyses, and trade studies.

Cost Estimating Community (CEC): The CEC at NASA is an increasingly cohesive group. NASA CEC falls into a different functional organization at each Center. Depending on the focus and the culture at the Center, the cost estimators are aligned with the most logical organization for the Center to access their cost estimating capability efficiently.

Cost Estimating Relationship (CER): A mathematical relationship that defines cost as a function of one or more parameters such as performance, operating characteristics, physical characteristics, etc.

Cost Estimating Working Group (CEWG): The purpose of the CEWG is to strengthen NASA's cost estimating standards and practices by focusing on improvement in tools, processes, and resources (e.g., training, employee development). Membership is comprised of senior cost estimating analysts from each NASA Center and JPL. The working group is also a forum to foster cooperation and interchange in areas such as sharing models and data across Centers and implementing "lessons learned".

Cost Estimation: The process of analyzing each hardware element, the buildup, integration and test of these elements, and the operation of the system over some specified life cycle (including disposal of the asset), with respect to the cost associated with the total effort.

Cost Estimation and Analysis (CEA) Competency: The total capability of an organization to provide the cost estimates required by the organization for budget planning and execution, and program planning and approval.

Cost Estimation and Analysis (CEA) Steering Group: This group is actively involved in establishing overall goals of the initiative, in decisions affecting the future of the CEA competency, in defining workforce and analysis tool requirements, and in the implementation of the initiative's elements. Group members represent the CEA-related interests of their home Centers, serve to share experiences (or lessons-learned) from cost analysis activities, and accept complementary responsibilities for various initiative actions. In addition, the group will facilitate an Agency-oriented CEA culture rather than a specific Center-oriented culture.

Cost Overruns: The amount by which actual costs exceed the baseline or approved costs. Cost overruns can also refer to the amount by which a contractor exceeds or expects to exceed the estimated costs, and/or the final limitations (the ceiling) of a contract.

Cost Performance/Schedule Trade Study: Systemic, interdisciplinary examination of the factors affecting the cost of a system to find methods for meeting system requirements at an acceptable cost. This is achieved by analyzing numerous system concepts to find ways to attain necessary performance while balancing essential requirements that must be satisfied for the system to be successful. The objective of the cost-performance trades is not to minimize the cost of the system, but to achieve a specified level of cost reduction established by the target costing system.

Cost Risk: Risk due to economic factors, rate uncertainties, cost estimating errors, and statistical uncertainty inherent in the estimate.

Cost/Schedule Control System Criteria (C/SCSC): A planning and control reporting system devised by the Department of Defense for its contractors to use, intended to foster greater uniformity as well as early insight into impending schedule or budget overruns.

Cost/Schedule Status Report (C/SSR): The low-end cost and schedule report generally imposed on smaller value contracts, not warranting full C/SCSC.

Cost Spreading Model: Takes the point-estimate derived from a parametric cost model and spreads it over the project's schedule, resulting in the project's annual phasing requirements.

Crystal Ball®: Software that employs an analytical technique, called Monte Carlo Simulation to provide the capability to conduct risk and uncertainty analyses within the construct of Excel-based models.

Cumulative Average Curve: Predicts the average unit cost of a set number of production units. Also, referred to as the *Wright curve* or the *Northrop curve*.

Cumulative Probability Distribution Curve ("S" Curve): A display of cumulative costs, labor hours or other quantities plotted against time. The name derives from the S-like shape of the curve, flatter at the beginning and end and steeper in the middle, which is typical of most activities (and whole project). The beginning represents a slow, deliberate but accelerating start, while the end represents a deceleration as the work runs out.

Decision Tree: A graphic representation of the sequence of a specific activity or operation.

Delphi: A process where a consensus view is reached by consultation with experts. Often used as an estimating technique.

Descriptive Statistics: Descriptive statistics provide basic information on the nature of a particular variable or set of variables. In general, descriptive statistics can be classified into three groups, those that measure 1) central tendency or location of a set of numbers (i.e., mode, median, mean, etc.), 2) variability or dispersion (i.e., range, variance, standard deviation, etc.), and 3) the shape of the distribution (i.e., moments, skewness, kurtosis, etc.).

Direct Costs: Direct costs are costs that are obviously and physically related to a project at the time they are incurred and are subject to influence of the project manager. Examples of direct costs include contractor-supplied hardware and project labor, whether provided by civil service or contractor employees.

Discount Factor: The discount factor translates projected cash flows into present value terms using specified discount factors. It is equal to $1(1+i)^n$ where i is the interest rate and n is the number of years from the date of initiation for the project. Discount factors can be reflected in real or nominal terms.

Discounted Cash Flow (DCF): A cash flow summary that has been adjusted to reflect the time value of money.

Discounting: Technique for converting forecasted amounts to economically comparable amounts at a common point or points in time, considering the time value of money.

Earned Value Management (EVM): A management technique that relates resource planning to schedules and to technical cost and schedule requirements. All work is planned, budgeted, and scheduled in time-phased increments constituting a cost and schedule measurement baseline.

Earned Value Management System (EVMS): A management system and related sub-systems implemented to establish a relationship between cost, schedule, and technical aspects of a project, measure progress, accumulate actual costs, analyze deviations from plans, forecast completion of events, and incorporate changes in a timely manner.

Economic Analysis (EA): Systematically identifies the costs and benefits of each suitable future course of action. An EA specifies the objectives and assumptions, addresses appropriate alternative courses of action, includes cost of the alternatives, and describes benefits and/or effectiveness of each alternative.

Economic Analysis Development Plan (EADP): Constructed prior to an Economic Analysis and should include, at a minimum, the mission, background, purpose, constraints, assumptions, cost element structure, cost and benefit estimating methodology, system description, configuration, schedules, and issues.

ECONPAK: Army-developed economic analysis tool, picked by HQs, to evaluate Construction of Facilities projects for Cost Benefit analyses.

e-Government: The Office of Electronic Government in the General Services Administration was formerly named the Office of Electronic Commerce. E-Government is about using technology to enhance access to and delivery of information and services to citizens, business partners, employees, agencies, and government entities.

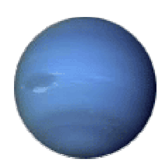
Environmental Quality Costs: Those costs that are specifically related to activities within the Army environmental program including pollution prevention, compliance, restoration, and conservation.

Environmental Quality Economic Analysis (EQEA): Supports decision making associated with environmental quality costing alternatives.

Estimate at Completion (EAC): Actual cost of work completed to date plus the predicted costs and schedule for finishing the remaining work. It can also be the expected total cost of an activity, a group of activities, or of the project when the defined scope of work is completed.

Expert Choice: Advanced decision support application that uses Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) to help quantify qualitative decisions.

Factor Cost Estimate: Cost factors are often used to address those program/project elements that must be accounted in the cost estimate but are largely undefined early in the design. Examples of cost elements that could be developed using factors and percentages include contractor fee, Advanced Development, Operations Capability Development, Program Support, and Center and agency taxes.



Federal Activities Inventory Reform (FAIR) Act: The FAIR Act directs Federal agencies to issue each year an inventory of all commercial activities performed by Federal employees, e.g., those activities that are not inherently governmental. OMB is to review each agency's Commercial Activities Inventory and consult with the agency regarding its content. Upon the completion of this review and consultation, the agency must transmit a copy of the inventory to Congress and make it available to the public. The FAIR Act establishes a limited administrative appeals process under which an interested party may challenge the omission or the inclusion of a particular activity on the inventory as a commercial activity. With completion of the inventory, including the challenge and appeals process, the FAIR Act requires agencies to review the activities on the inventory.

Front-end Analysis: Front-end analysis is comprised of two parts: a needs assessment and a task analysis. A needs assessment is the systematic effort to gather opinions and ideas from a variety of sources on performance problems or new systems and technologies. Task analysis breaks down job tasks into steps and solves performance problems. Task analysis works to determine the operational components of an objective, describe what and how they are to be performed, describe the sequence and describe the scope.

Full Cost Accounting: Full cost accounting ties all Agency costs (including civil service personnel costs) to major activities. All costs will be associated with an activity and, as a result, referred to as a cost object.

Function Point Analysis (FPA): A standard methodology for measuring software development and maintenance using function points. Function points is a standardized metric that describes a unit of work product suitable for quantifying software that is based on the end-user's point of view.

Functional Economic Analysis (FEA): Economic Analysis type that documents the review of an entire functional process or sub-process, such as the use of alternative launch vehicles, etc. It requires a risk assessment of each alternative solution, requesting a high and low estimate for each cost element and subsequent probability distribution of expected costs.

Future Value (FV): Value a specified number of years in the future, after the interest earned has been added to the account.

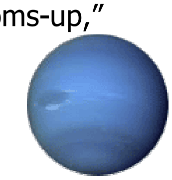
Gap Analysis: Step Two in the CBA process. After evaluation of the current environment, the results of the current process are compared to the investment's stated objectives (i.e., a "to-be" environment). The outcome of this comparison enables determination of current environment shortfalls and identifies change opportunities. The gaps between where the organization is today and how it wants to look after the investment represent the opportunities for improvement.

General and Administrative (G&A) Cost: G&A costs are costs that cannot be related or traced to a specific project, but benefit all activities. Such costs are allocated to a project based on a reasonable, consistent basis. Examples of G&A costs include costs associated with financial management, procurement, security, and legal activities.

Government-Off-The-Shelf (GOTS): GOTS are pre-packaged software or (less commonly) hardware purchase alternatives. The technical staff of the government agency for which it is created typically develops them. It is sometimes developed by an external entity, but with funding and specification from the agency. Because agencies can directly control all aspects of GOTS products, these are generally preferred for government purposes.

Grassroots Cost Estimating: This costing methodology approach involves the computation of the cost of a WBS element by estimating the labor requirements (in terms of man-hours or man-years, for example) and the materials costs for the specific WBS line item. It is also referred to as "bottoms-up," or engineering build-up estimating.

Ground Rules and Assumptions (GR&A): Ground rules and assumptions are external circumstances or events that are believed likely to happen. Ground rules and assumptions are



based on the operation, maintenance and support of the system. Ground rules and assumptions generally include: the O&M period, base year of dollars, type of dollars, inflation indices, costs to be included or excluded, guidance on how to interpret the estimate properly, and clarification to the limit and scope in relation to acquisition milestones.

Independent Cost Estimate (ICE): Prepared as a result of an independent review of a program/project. ICEs are developed by the cost analyst members of the independent review team in order to provide program/project management with the review team's assessment of how realistic the project's life cycle costs are.

Independent Life Cycle Cost Estimate: A life cycle cost estimate developed outside normal channels which generally includes representation from cost analysis, procurement, production management, engineering and project management.

Independent Program Assessment Office (IPAO): The IPAO is a headquarters office located at Langley Research Center (LaRC). The IPAO role in cost estimating is to provide leadership and strategic planning for the cost estimation core competency by: interfacing with the Agency CFO and the Office of the Chief Engineer (Code AE) at NASA Headquarters regarding cost analysis requirements and processes, providing instruction on cost tool use, developing specialized cost tools, ensuring consistent, high-quality estimates across the Agency, fostering a "pipeline" of competent NASA analysts, providing independent, non-advocate cost estimates and cost-benefit analyses, and chairing the Cost Estimating Working Group and the annual NASA Cost Symposium Workshop.

Indirect Costs: Costs, which, because of their incurrence for common or joint objectives, are not readily subject to treatment as direct costs.

Inflation: An increase in the volume of money and credit relative to available goods and services resulting in a continuing rise in the general price level.

Integration Complexity Risk: Includes risks associated with the number of data dependencies, the number of actual interfaces between this module and other modules, and the technical issues involved regarding programming and application solutions.

Intelligent Synthesis Environment (ISE): The Intelligent Synthesis Environment (ISE) program is a NASA initiative to develop a virtual reality design environment. The goal is an advancement of the simulation based design environment involving the integration of design and cost models with analytical tools using intelligent systems technology. As a result of this new environment, the time to develop new system designs and to estimate the costs will be greatly reduced.

Interest: The service charge for the use of money or capital, paid at agreed to intervals by the user, and commonly expressed as an annual percentage of principal.

Internal Rate of Return (IRR): The Internal Rate of Return (IRR) is another ROI metric used to measure an investment. The IRR is defined as the rate at which a bond's future cash flows, discounted back to today, equal its price. It is also defined as discount rate at which the NPV equals zero. IRR can be estimated using the formula:

IRR = NPV = PV Benefits - PV Costs = 0.

Learning Curve: Learning curves, sometimes referred to as *improvement curves* or *progress functions*, are based on the concept that resources required to produce each additional unit decline as the total number of units produced increases. The term learning curve is used when an individual is involved and the terms progress function or an improvement curve is used when all the components of an organization are involved. The learning curve concept is used primarily for uninterrupted manufacturing and assembly tasks, which are highly repetitive and labor intensive.

Lease: A lease is a long-term agreement between a user (lessee) and the owner of an asset (lessor) where periodic payments are made by the lessee in exchange for most of the benefits of ownership.

Lease vs. Buy Decision: The Lease vs. Buy decision has three steps: estimate the cash flows associated with borrowing and buying the asset, estimate the cash flows associated with leasing and asset, and compare the two financing methods to determine which has the lower cost. The decision rule for the acquisition of an asset is: buy the asset if the equivalent annual cost of ownership and operation is less than the best lease rate that can be acquired from an outsider.

Lessee: Renter or the user of the asset. Lessee contracts to make a series of payments to the lessor, and in return, gets to use the asset for the lease term.

Lessor: Legal owner and normally is entitled to the tax privileges of ownership like depreciation deductions or investment tax credits, if they are available. At the end of the lease period, the equipment reverts to the lessor.

Level of Effort (LOE): Effort of a general or supportive nature which does not produce definite end products or results, i.e., contract for man-hours.

Life Cycle Cost (LCC): The total cost for all phases of a project or system including design, development, production, operations, and disposal. It is also referred to as a *benefit-cost analysis*.

Life Cycle Cost Estimate (LCCE): Presents life cycle costs with alternatives, by comparing the current estimate to the independent estimate (or prior estimate).

Linear Regression: A statistical technique used to illustrate how a linear relationship between two variables (namely X and Y) can be quantified using appropriate data. It is also referred to as *Simple Regression*.

Logical Decisions for Windows: Software that allows evaluation of numerous alternatives based on a hierarchy of goals and objectives.

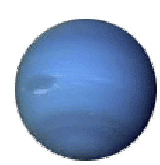
Manual Software Estimation: Manual software estimation typically utilizes a simple, straightforward methodology to derive effort, cost, and schedule. This includes analogy, engineering buildup, or cost estimating relationship (CER) factors.

Market Risk: Includes risks associated with the stability of vendors and their software and related tools and services within the market (in this case federal HR commercial off-the-shelf [COTS] product market).

Monte Carlo Simulation: Calculates numerous scenarios of a model by repeatedly picking random values from the input variable distributions for each "uncertain" variable and calculating the results.

Multivariate Regression: A statistical technique used to illustrate how a relationship between multiple variables can be quantified using appropriate data.

NASA / Air Force Cost Model (NAFCOM): An innovative computer model for estimating aerospace program costs. NAFCOM96 is a user-friendly estimating tool, which operates in the Microsoft Windows environment. The model gives users flexibility in estimating by accommodating up to five systems and ten WBS levels, and by providing the user with the option of inputting throughput hardware or integration cost or allowing the model to calculate the cost using NAFCOM96 estimating methodology or user defined equations.



NASA Research Announcement: An NRA is used to announce research in support of NASA's programs, and, after peer or scientific review using factors in the NRA, select proposals for funding. Unlike an RFP containing a statement of work or specification to which offerors are to respond, an NRA provides for the submission of competitive project ideas, conceived by the offerors, in one or more program areas of interest. NRAs may result in grants, contracts or cooperative agreements.

Net Present Value (NPV): Project's net contribution to wealth; Present Value minus Initial Investment.

Nominal Discount Rate: The nominal discount rate is adjusted to reflect expected inflation used to discount *Then Year* (inflated) dollars or nominal benefits and costs.

Non-Developmental Item (NDI): Non-Developmental Items (NDI) are items, other than real property, that are customarily used for Non-Government purposes.

Non-Linear Regression: Type of regression used for data that is not intrinsically linear. Techniques for non-linear regression include: nonlinearity removed by logs, logs as relative changes and utilizing commercial software for modeling non-linear data.

Non-Quantifiable Benefits: Benefits that are able to be measured and therefore quantified. Non-quantifiable benefits include enhanced information security, consistency and compatibility throughout the enterprise, improved quality, enhancement of best practices, adherence to statutory and regulatory requirements, and enhanced modernization.

Normalize: Database to render constant or to adjust for known differences. Dollars, previous-year costs are escalated to a common-year basis for comparison.

Operating and Maintenance Costs (O&M): Those operating expenditures incurred in the normal course of business to operate, maintain, support and update the system. It is also referred to as **recurring costs**.

Ordinary Least Squares (OLS): Regression technique that works to find the best possible equation (relationship) between variables while minimizing the squares of error terms.

Parametric Cost Estimate: An estimating methodology using statistical relationships between historical costs and other project variables such as system physical or performance characteristics, contractor output measures, or manpower loading, etc. Also referred to as *"top down"* estimating.

Parametric Estimation: Involves the development and utilization of cost estimation relationships between historical costs and program, physical, and performance characteristics. The analysis uses analysis tools, or models, that relate hardware elements, complexity, and risks of failure to expected costs – a parametric analysis.

Payback Period: The payback period is the time required for the cumulative value of savings to be equal to the cumulative value of investment. The payback period measures the number of years needed to recover the investment or break even. The accept-reject criterion for this financial indicator is the ability of the program to equal or better the organization's required payback period.

Point Estimate: Take a sample and then calculate the sample mean, sample variance, etc.

Present Value: Reflects in today's terms the value of future cash flows adjusted for the cost of capital - the time value of money. Present value is calculated from the time series of constant dollars estimates, using the real discount rate as specified by OMB policy.

President's Management Agenda (PMA): The PMA identifies government-wide and program initiatives. Of these initiatives, there are four that directly relate to NASA: Competitive Sourcing, Improved Financial Performance, Budget and Performance Integration, and Better R&D Investment Criteria.

PRICE H/HL/M: A suite of hardware parametric cost estimating models that accurately estimate development, production, and operations and support costs. The suite allows for generating estimates at any WBS level, which includes integration and test cost calculations. The models operate in Microsoft Windows and interface with Microsoft Excel, Project, and other office tools. Monte Carlo risk simulations capability is available with the suite.

PRICE S: A suite of software sizing, development cost, and schedule, along with associated software operations and support cost models. The models operate in Microsoft Windows and interface with Microsoft Excel, Project, and other office tools. Monte Carlo risk simulations capability is available with the suite.

Productivity Paradox: The productivity paradox is a phenomenon where the programming language that seems to have the best productivity metrics (e.g. effort per SLOC), actually results in the highest total cost because the language is less efficient than other, more modern programming languages.

Program: An activity involving the development and operation of a hardware system, or more specifically, a space system.

Program Commitment Agreement (PCA): The contract between the NASA Administrator and the Associate Administrator for Space Science for the implementation of a program in terms of cost, schedule, and content.

Program Office Estimate (POE): A detailed estimate of acquisition and ownership costs normally required for high-level decisions. The estimate is performed early in the program and serves as the base point for all subsequent tracking and auditing purposes.

Program Work Breakdown Structure (WBS): A family tree, usually product oriented, that organizes, defines, and graphically displays the hardware, software, services, and other work tasks necessary to accomplish the project objectives.

Project Schedule Risk: Project Schedule risks are risks that the module implementation will be successful and run according to planned schedule. Schedule risk is defined as uncertainty in the project completion or fielding schedule, and the subsequent impact on costs and level of benefits. A stretched-out schedule may increase costs due to extended level-of-effort funding requirements, and result in delivery of systems too late to have the desired effect (reduced benefits). This category also addresses factors such as the thoroughness of project approach and plan, the degree to which plans incorporate risk mitigation techniques, and the impact of not meeting or adjusting the project's anticipated timeline.

Quantifiable Benefits: Quantifiable benefits are those that can be measured or assigned a numeric value, such as dollars, physical count of tangible items, time, revenue, or percentage change. Dollar valued benefits comprise cost reductions, cost avoidance, and productivity improvements. Quantifiable benefits are calculated by subtracting the cost of an alternative from the cost of baseline operations over the period of the estimate (normally 10 years for IT investments). The difference is the "savings" that is often referred to as ROI.

Real Discount Rate: Discount rate adjusted to eliminate the effects of expected inflation used to discount Constant Year dollars or real benefits and costs.

Real Options Approach: The real options approach is a financial technique for valuing investment alternatives. This approach is primarily a decision tool that indicates whether or not to proceed with an investment after pre-established decision points are reached. This approach is more suited to large scale, multi-year acquisition projects where NASA would need to decide whether to continue spending or abandon a specific project. This approach integrates NPV techniques with a decision-tree framework to determine the whether a project should proceed or be terminated.

Regression Analysis: A quantitative technique used to establish a line-of-best-fit through a set of data to establish a relationship between one or more independent variable and a dependent variable. That line is then used with a projected value of the independent variable(s) to estimate a value for the dependent variable.

Request for Proposal (RFP): A formal invitation containing a scope of work, which seeks a formal response (proposal) describing both methodology and compensation to form the basis of a contract. The Request For Proposal consists of a Solicitation Letter, Instructions to Bidders, Evaluation Criteria, Statement of Work, and a System Specification. The provider issues an RFP to potential subcontractors.

Reserve: A provision in the project plan to mitigate cost and/or schedule risk. Often used with a modifier (e.g., management reserve, contingency reserve) to provide further detail on what types of risk are meant to be mitigated.

Return on Investment (ROI): The strict meaning of ROI is "Return on Invested Capital." Most business people, however, use "ROI" simply to mean the incremental gain from an investment, divided by the cost of the investment. ROI is the net benefit expressed as a percentage of the investment amount:

$$ROI = NPV / PV\ Investment$$

REVIC: Parametric software cost estimating tool distributed by the Air Force Cost Analysis Agency that implements the Intermediate Constructive Cost Model (COCOMO) developed and described by Dr. Barry Boehm in his book Software Engineering Economics.

Risk: A situation in which the outcome is subject to an uncontrollable event stemming from a known probability distribution.

Risk Analysis: Process of examining each identified risk area to: isolate the cause; investigate the associative risk effects (e.g. dependencies/correlations); and determine the probable impacts.

Risk Assessment: Process of identifying and analyzing critical process and entity risks to increase the likelihood of meeting cost, performance (technical), and schedule objectives.

Rough Order of Magnitude (ROM) Estimates: It is an estimated cost based on approximate cost models or expert analysis. It is usually based on top-level requirements or specifications, and an overall prediction of work to be done to satisfy the requirements. The ROM is usually used for financial planning purposes only.

Savings to Investment Ratio (SIR): The NPV of the savings divided by the NPV of the investment. The savings is the difference in the recurring costs between the status quo alternative and the proposed alternative. When the SIR equals one then discounted payback occurs.

Service Cost: Service costs are costs that cannot be specifically and immediately identified to a project, but can subsequently be traced or linked to a project and are assigned based on usage or consumption. Examples of services costs include automatic data processing and fabrication.

Scope of Work: The work involved in the design, fabrication and assembly of the components of a project's deliverable into a working product.

SEER-DFM: A software tool used to evaluate product and manufacturing costs, improves productivity and quality, and speeds products to market. (Design for Manufacturability)

SEER-H: A development and production estimation and management tool that predicts, measures, and analyzes resources, materials and schedules for an array of products and complex systems. It presents a view of the operational and maintenance costs of a product throughout its life cycle. (Hardware Estimation and Life Cycle Cost Analysis)

SEER-IC: A complement to SEER-H, helps estimate custom integrated circuit development and production costs, generate specifications, and evaluate potential yields. (Custom Integrated Circuit Development)

SEER-SEM: A development and program management tool that predicts, measures, and analyzes costs, schedules, risks, and reliability for software projects. (Software Estimation Model)

SEER-SSM: A software-sizing tool that creates realistic and highly reliable estimates of a project's scope. (Software Sizing Model)

Sensitivity Analysis: A technique used to discover how sensitive the results from economic and financial models are to changes in the input values of the variables used to calculate the results. A high degree of sensitivity is a warning to interpret the results of the model with care and circumspection, especially because many of the input variables themselves, will have been estimated and therefore be subject to error. Use of econometric models must not obscure awareness of their limitations and possible pitfalls, especially when they are being used for forecasting.

Should Cost Analysis: A study of contract price, which reflects reasonably achievable contractor economy and efficiency. It is accomplished by a government team of procurement, contract administration, audit and engineering representatives performing an in-depth cost analysis at the contractor's and subcontractor's plants. Its purpose is to develop a realistic price objective for negotiation purposes.

Software Size: How big the application is being developed.

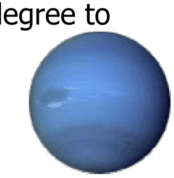
Source Lines of Code (SLOC): Counting physical SLOC is accomplished by tallying the number of carriage returns in the source document. Logical SLOC are counted by tallying logical units (e.g., an IF-THEN-ELSE statement is considered one logical unit). SLOC methodology is based upon estimating the lines of code (deliverable) and the man-months effort required to develop a software program, with the advice of Subject Matter Experts (SMEs).

Space Operations Cost Model (SOCM): A suite of tools to estimate space mission operations costs for future NASA projects. The estimating methodology is based on a mix of parametric estimating relationships derived from collected data and constructive approaches capturing assessments of advanced technology impacts and reflecting experience from current mission planning teams. At completion, SOCM will include modules for Planetary and Earth Orbiting robotic science missions, Orbiting Space Facilities, Launch/Transportation Systems, and Human Spaceflight (Lunar/Mars) missions.

Status Quo System: The system as it currently exists.

Target Costing: Structured approach to determine the cost at which a system or product with specified performance and reliability must be produced to shift the decision point toward proceeding with the project.

Technical Risk: Technical risk is defined as uncertainty in the system performance or "benefits." Technical risk may result from an immature technology, use of a lower-reliability component, degree to which products employ the latest standards in technology and design, availability of skilled resources to support the product, and then degree of tailoring required. Technical risk can be reflected in increased costs (to fix the technical problem) and lower overall system benefits.



Then-Year Dollars (TY): Dollars that are escalated into the time period of performance of a contract. Sometimes referred to as escalated costs, inflated costs, or real-year dollars.

Time Phased: Related to the deployment schedule and operating concept, shows costs over time.

Time Value of Money: The time value of money refers to the fact that a dollar in hand today is worth more than a dollar promised at some future time. By compounding and discounting, the time value of money adjusts cash flow to reflect the increased value of money when invested. The time value of money also reflects that benefits and costs are worth more if they are realized earlier.

Tool-Driven Software Estimation: Tool-driven software estimation can produce more thorough and reliable estimates than manual methods. These parametric tools are based on data collected from hundreds or thousands of actual projects. The algorithms that drive them are derived from the numerous inputs to the models from personnel capabilities and experience and development environment to amount of code reuse and programming language.

Total Cost of Ownership (TCO): Sum of all financial resources necessary to organize, equip, train, sustain, and operate military forces sufficient to meet national goals in compliance with all laws, all policies applicable to DoD, all standards in effect for readiness, safety, and quality of life, and all other official measures of performance for DoD and it's components. TOC is comprised of cost to research, develop, acquire, own, operate, and dispose of weapon and support systems, other equipment and real property, the costs to recruit, train, retain, separate and otherwise support military and civilian personnel, and other cost of business operations in DoD.

Uncertainty: A situation in which the outcome is subject to an uncontrollable event stemming from an UNKNOWN probability distribution.

Unit Curve: Predicts unit values for a given point on the curve. It is a plot of the cost of each unit of a given quantity. The total cost for the given quantity in the sum of the cost of each individual unit. Also referred to as the *Crawford* or *Boeing* curve.

Value Engineering: Used in the product design stage to find ways to achieve the specified performance at the required level of performance and reliability at the target cost. Value engineering is implemented in practice through cost-performance trades of design concepts.

Variance: A measure of the degree of spread among a set of values; a measure of the tendency of individual values to vary from the mean value. It is computed by subtracting the mean value from each value, squaring each of these differences, summing these results, and dividing this sum by the number of values in order to obtain the arithmetic mean of these squares.

Vendor Quote: Obtaining actual costs on WBS items such as hardware, facilities, or services, directly from the vendor who provides it.

Work Breakdown Structure (WBS): A technique for representing all the components, software, services and data contained in the project scope statement. It establishes a hierarchical structure or product oriented "family tree" of elements. It is used to organize, define and graphically display all the work items or work packages to be done to accomplish the project's objectives.

"What-If" Analyses: The process of evaluating alternative strategies.

Wrap Rate: NASA wrap rates can be defined as those additional service pools (charges) that should be included in project/program estimates because they are a part of doing business from which projects/programs receive benefit. Examples (not all inclusive) of these service charges or additional costs can include such items as: system engineering, project management, workstation maintenance, application programming, computer usage, facilities, and fabrication.

C. References

This appendix provides a convenient, though not comprehensive, list of references for cost estimating. Some of these references were used in compiling this handbook; others should prove useful to the NASA CEC. This appendix is organized by reference type (e.g., books, websites, manuals, etc.,) and by topic. In addition to the references listed below, a good locator source is the Library of Congress Online Catalog, which can be found at http://catalog.loc.gov/.

Books

2002 Craftsman Cost Estimating Guides

Advanced Engineering Economics (by Chan S. Park and Gunter P. Sharp-Bette)

Construction Cost Analysis and Estimating (by Phillip F. Ostwald)

Cost Estimating (by Rodney D. Stewart)

Cost Estimator's Reference Manual (by Rodney D. Stewart, Richard M. Wyskida, and James D. Johannes)

Design to Cost (by Jack V. Michaels and William P. Wood)

Engineering Cost Estimating (by Phillip F. Ostwald)

Estimating and Bidding for Heavy Construction (by S.H. Bartholomew)

Estimating in Building Construction (by Frank R. Dagostino and Leslie Feigenbaum

Estimating Software Costs (by T. Capers Jones)

Financial Management Theory and Practice (by Eugene F. Brigham and Michael C. Gapenski)

How to Estimate with Means Data & CostWorks (by Saleh Mubarak and Means)

Investment Under Uncertainty (by Avinash Dixit and Robert Pindyck)

Managing the Construction Process: Estimating, Scheduling, and Project Control (by Frederick E. Gould)

Means Building Construction Cost Data (by R.S. Means Company, Inc.(http://www.rsmeans.com)

Principles of Corporate Finance (by Richard A. Brealey and Stewart C. Myers)

Real Options; Managerial Flexibility and Strategy in Resource Allocation (by Lenos Trigeorgis)

Real Options: Managing Strategic Investments in an Uncertain World (by Martha Amram and Nalin Kulatilaka)

Reducing Space Mission Cost (by James R. Wertz and Wiley J. Larson)

Simplified Estimating For Builders And Engineers (by Joseph E. Helton)

Software Cost Estimation with COCOMO II (by Barry W. Boehm)

Space Mission Design and Analysis (SMAD) (by Wiley J. Larson and James Richard Wertz)

Technological Forecasting for Decision Making (by Joseph P. Martino)

Walker's Building Estimator's Reference Book (by Scott Siddens and Frank R. Walker Co.)

Handbooks and Manuals

Air Force Space Command (AFSC) Cost Estimating Handbook Series, Volume VI - Space Handbook

Department of the Army Cost Analysis Manual
http://www.ceac.army.mil/default.htm

Department of the Army Economic Analysis Manual
http://www.asafm.army.mil/pubs/cdfs/manual/economic.pdf

Department of Defense Operating and Support Cost Estimating Guide
http://www.ncca.navy.mil/resources/caig_os_guide.pdf

Department of Defense Parametric Estimating Initiative Handbook
http://www.ispa-cost.org/PEIWeb/newbook.htm

Department of the Navy Center for Cost Analysis Software Development Estimating Handbook

NAFCOM Manual

NASA Systems Engineering Handbook
http://ldcm.gsfc.nasa.gov/library/NASA%20Syst%20Eng%20Handbook.pdf

PRICE Manual

SEER Manual

Policies, Procedures, and Guidelines

To find NASA Agencywide directives please reference the NASA Online Directives Information System (NODIS) at http://nodis3.gsfc.nasa.gov/library/main_lib.html.

NASA Policy Directives

NPD 1000.1B: NASA Strategic Plan
http://nodis3.gsfc.nasa.gov/library/displayDir.cfm?Internal_ID=N_PD_1000_001B_&page_name=main

NPD 7120.4B: Program/Project Management
http://nodis3.gsfc.nasa.gov/library/displayDir.cfm?Internal_ID=N_PD_7120_004B_&page_name=main&search_term=7120

NASA Procedures and Guidelines

NPD 9501.5G: NASA Contractor Financial Management Reporting System
http://nodis3.gsfc.nasa.gov/library/displayDir.cfm?Internal_ID=N_PD_9501_001G_&p

NPG 1000.3: The NASA Organization
http://nodis3.gsfc.nasa.gov/library/displayDir.cfm?Internal_ID=N_PG_1000_0003_&page_name=main&search_term=1000

NPG 7120.5A: Program and Project Management Processes and Requirements[21]
http://nodis3.gsfc.nasa.gov/library/displayDir.cfm?Internal_ID=N_PG_7120_005A_&page_name=main

NPG 7500.1: NASA Technology Commercialization Process
http://nodis3.gsfc.nasa.gov/library/displayDir.cfm?Internal_ID=N_PG_7500_0001_&page_name=main

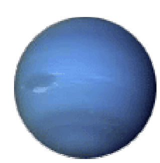
NASA Procedures and Guidelines Directive No. 210-PG-5100.1.1
Purchase Request (PR) Initiator Documentation Guide for Simplified Acquisitions
http://msc-docsrv.gsfc.nasa.gov/GDMS_docs/Pgwi200/210-PG-5100.1.1-.pdf

Other Federal Agency Guidelines

Contract Pricing Reference Guides
http://www.acq.osd.mil/dp/cpf/pgv1_0/

Cost Analysis Improvement Group (CAIG) Operating and Support Cost Estimating Guide
http://www.dtic.mil/pae/

DoD 5000.2-R Mandatory Procedures for Major Defense Acquisition Programs (MDAPS) and Major Automated Information System (MAIS) Acquisition Programs
http://www.acq.osd.mil/ar/doc/dodd5000-2-r-061001.pdf
DoD 5000.4 Cost Analysis Improvement Group (CAIG)
http://www.dtic.mil/whs/directives/corres/pdf/d50004wch1_112492/d50004p.pdf



[21] *NPG 7120.5B will be released soon.*

DoD 5000.4-M Cost Analysis Guidance and Procedures
http://www.hanscom.af.mil/ESC-BP/pollprev/docs/50004m.pdf
http://www.dtic.mil/whs/directives/corres/html/50004m.htm
http://web1.deskbook.osd.mil/default.asp (Search for DoD 5000.4-M)

The Federal Activities Inventory Reform Act (FAIR), P.L. 105-270
http://www.whitehouse.gov/omb/procurement/fair-index.html

JPL Formal Cost Estimation Procedure (JPL D-16376)
Hamid Habib-agahi, Cost Estimation Process Owner
David B. Smith, Manager, Product Delivery Engineering Office

Military Standard 881
http://www.kolacki.com/MIL-HDBK-881.htm

NASA FY2003 Congressional Budget
http://ifmp.nasa.gov/codeb/budget2003/

NASA Federal Acquisition Regulation (FAR) Supplement
http://www.hq.nasa.gov/office/procurement/regs/nfstoc.htm

NASA Full Cost Initiative Agencywide Implementation Guide
http://ifmp.nasa.gov/codeb/library/fcimplementation.pdf

Office of Management and Budget (OMB) Circular No. A-11
Preparing and Submitting Budget Estimates
http://www.whitehouse.gov/omb/circulars/a11/2001_A-11.pdf

Office of Management and Budget (OMB) Circular No. A-76
Performance of Commercial Activities
http://www.whitehouse.gov/omb/circulars/a076/a076.html

Office of Management and Budget (OMB) Circular No. A-76
Performance of Commercial Activities Revised Supplemental Handbook
http://www.whitehouse.gov/omb/circulars/a076/a076s.html

Office of Management and Budget (OMB) Circular No. A-94
Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs
http://www.whitehouse.gov/omb/circulars/a094/a094.html

Office of Personnel Management Salary Tables
http://www.opm.gov/oca/payrates/

Title 10 United States Code Section 2306a (10 USC 2306a)
Cost or Pricing Data: Truth in Negotiations
http://www4.law.cornell.edu/uscode/10/2306a.html

Papers and Reports

Aerospace Systems Design in NASA's Collaborative Engineering Environment
http://techreports.larc.nasa.gov/ltrs/PDF/1999/mtg/NASA-99-50iac-dwm.pdf

GAO Defense Acquisition: Historical Insights Into Navy Ship Leasing
http://www.gao.gov/archive/1999/ns99141t.pdf

The President's Management Agenda
http://w3.access.gpo.gov/usbudget/fy2002/pdf/mgmt.pdf

Report of the Advisory Committee On the Future of the U.S. Space Program
http://history.nasa.gov/augustine/racfup1.htm

Software Size Measurement: A Framework for Counting Source Statements (by Robert E. Park)
http://www.sei.cmu.edu/pub/documents/92.reports/pdf/tr20.92.pdf

Professional Societies

American Institute of Aeronautics and Astronautics (AIAA)
http://www.aiaa.org/menu.hfm

American National Standards Institute (ANSI)
http://www.ansi.org/

American Society of Professional Estimators (ASPE)
http://www.aspenational.com/

Association for the Advancement of Computing in Education
http://www.aace.org/

The Association for the Advancement of Cost Engineering through Total Cost Management (AACE) International
http://www.aacei.org/

Association of Cost Engineers (ACostE)
http://www.acoste.org.uk/

Center for International Project and Program Management (CIPPM)
http://www.iol.ie/~mattewar/CIPPM/

International Cost Engineering Council (ICEC)
http://www.icoste.org/

International Function Point Users Group (IFPUG)
www.ifpug.org

International Project Management Association (IPMA)
http://www.ipma.ch/

International Society of Parametric Analysts (ISPA)
http://www.ispa-cost.org/

National Contract Management Association (NCMA)
http://www.ncmahq.org/

Project Management Institute (PMI)
http://www.pmi.org/

Society of Cost Estimating and Analysis (SCEA)
http://www.sceaonline.net/

Society for Risk Analysis (SRA)
http://www.sra.org/

Space Systems Cost Analysis Group (SSCAG)
http://sscag.saic.com/

General NASA Websites

Aerospace Technology Enterprise
http://www.aero-space.nasa.gov/

Ames Research Center
http://www.arc.nasa.gov/

Ames Research Center Educational Site
http://education.arc.nasa.gov/

Biological and Physical Research Enterprise
http://www.hq.nasa.gov/office/olmsa/

Chief Financial Officer
http://ifmp.nasa.gov/codeb/

Budget Request
http://ifmp.nasa.gov/codeb/budget2003/

Dryden Flight Research Center
http://www.dfrc.nasa.gov/

Earth Science Enterprise
http://www.earth.nasa.gov/

External Relations
http://www.hq.nasa.gov/office/codei/

Glenn Research Center
http://www.grc.nasa.gov/

Goddard Space Flight Center
http://www.gsfc.nasa.gov/

Goddard Institute for Space Studies
http://www.giss.nasa.gov/

Wallops Flight Facility
http://www.wff.nasa.gov/

Human Exploration and Development of Space Enterprise
http://www.hq.nasa.gov/osf/heds/

Office of Space Flight
http://www..hq.nasa.gov/osf/

Human Resources and Education
http://www.hq.nasa.gov/office/codef/

Independent Validation and Verification Facility
http://www.ivv.nasa.gov/

Inspector General
http://www.hq.nasa.gov/office/oig/hq/

Java EOSDIS Acronym Finder
http://daac.gsfc.nasa.gov/CAMPAIGN_DOCS/MODIS/documentation/eosdis_acronym.shtml

Jet Propulsion Laboratory
http://www.jpl.nasa.gov/

Johnson Space Center
http://www.jsc.nasa.gov/bu2/

White Sands Test Facility
http://www.wstf.nasa.gov/

Kennedy Space Center
http://www.ksc.nasa.gov/

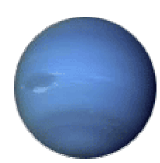
Langley Research Center
http://www.larc.nasa.gov/

Legislative Affairs
http://www.hq.nasa.gov/office/legaff/

Marshall Space Flight Center
http://www.msfc.nasa.gov/

NASA Acronym List (GSFC)
http://library.gsfc.nasa.gov/Databases/Acronym/acronym.html

NASA Acronym List (MSFC)
http://liftoff.msfc.nasa.gov/help/acronym.html



NASA Advisory Council
http://www.hq.nasa.gov/office/codez/nac/nac.htm

NASA Earth Science Acronyms
http://gcmd.gsfc.nasa.gov/Aboutus/sitemap.html

NASA Financial Management Manual
http://www.hq.nasa.gov/fmm/

NASA Headquarters
http://www.hq.nasa.gov/

NASA Homepage
http://www.nasa.gov/

NASA Human Space Flight
http://spaceflight.nasa.gov/

NASA HQ Office of the Chief Engineer
http://www.hq.nasa.gov/office/codea/codeae/

NASA ISO 9000 Certification
http://www.hq.nasa.gov/hqiso9000/

NASA Lessons Learned Information System
http://llis.nasa.gov/

NASA Online Directives Information System (NODIS)
http://nodis3.gsfc.nasa.gov/library/main_lib.html

NASA Spacelink
http://spacelink.nasa.gov/

NASA Strategic Management Handbook
http://www.hq.nasa.gov/office/codez/strahand/frontpg.htm

NASA Strategic Plan
http://www.hq.nasa.gov/office/nsp/

NASA HQ Systems Management Office (SMO)
http://www.hq.nasa.gov/office/codea/codeae/smo.html

NASA Watch
http://www.nasawatch.com/

Procurement
http://www.hq.nasa.gov/office/procurement/

Public Affairs
http://www.nasa.gov/newsinfo/index.html

Safety and Mission Assurance
http://www.hq.nasa.gov/office/codeq/

Science@NASA
http://science.nasa.gov/default.htm

Small and Disadvantaged Business Utilization
http://www.hq.nasa.gov/office/codek/

Space Science Enterprise
http://www.hq.nasa.gov/office/oss/

Stennis Space Center
http://www.ssc.nasa.gov/

Cost Analysis

Air Force Cost Analysis Agency (AFCAA)
http://www.saffm.hq.af.mil/afcaa/

Army Cost & Economic Analysis Center (CEAC)
http://www.ceac.army.mil/

Carnegie Mellon Software Engineering Institute
http://www.sei.cmu.edu/sei-home.html

Contract Pricing Reference Guides
http://www.acq.osd.mil/dp/cpf/pgv1_0/

Cost Analysis Division of European Space Agency (ESA)
http://www.estec.esa.nl/eawww/

Cost Analysis Requirements Description (CARD) References
http://www.kolacki.com/CARD.htm

Cost Estimating Acronym Glossary
http://www.jsc.nasa.gov/bu2/acronyms.html

Cost Estimating Databases
http://www.jsc.nasa.gov/bu2/data.html

Cost Estimating Glossary
http://www.jsc.nasa.gov/bu2/glossary.html

Cost Estimating References
http://www.jsc.nasa.gov/bu2/references.html

Cost Estimating Resources
http://www.jsc.nasa.gov/bu2/resources.html

Department of Energy Office of Science Article on Learning Curves
http://www.sc.doe.gov/sc-80/sc-82/430-1/430-1-chp21.pdf

Environmental Costs of Hazardous Operations (ECHO) Model
http://www.tecolote.com/Services/Models.htm

Formal Risk Assessment of System Cost Estimates (FRISK)
http://web2.deskbook.osd.mil/valhtml/2/2B/2B4/2B4S06.HTM

Inflation Calculator
http://www.jsc.nasa.gov/bu2/inflate.html

JSC Cost Estimating
http://www.jsc.nasa.gov/bu2/about.html

Labor and Materials
http://www.jsc.nasa.gov/bu2/instruct.html

The Learning Curve Article by Computerworld
http://www.computerworld.com/cwi/story/0,1199,NAV47-68-85-1942_STO61762,00.html

Learning Curve Calculator
http://www.jsc.nasa.gov/bu2/learn.html

NASA Online Cost Models
http://www.jsc.nasa.gov/bu2/models.htm

Advance Missions
http://www.jsc.nasa.gov/bu2/PCEHHTML/pceh.htm

Aircraft Turbine Engine
http://www.jsc.nasa.gov/bu2/ATECM.html

Airframe
http://www.jsc.nasa.gov/bu2/airframe.html

CPI Inflation Calculator
http://www.jsc.nasa.gov/bu2/inflateCPI.html

Cost Estimating Cost Model
http://www.jsc.nasa.gov/bu2/CECM.html

Cost Spreading Model
http://www.jsc.nasa.gov/bu2/beta.html

ECI Inflation Calculator
http://www.jsc.nasa.gov/bu2/inflation/eci/inflateECI.html

GDP Deflator Inflation Calculator
http://www.jsc.nasa.gov/bu2/inflateGDP.html

IPI Inflation Calculator
http://www.jsc.nasa.gov/bu2/inflation/ipi/inflateIPI.html

Labor & Material
http://www.jsc.nasa.gov/bu2/instruct.html

Learning Curve Calculator
http://www.jsc.nasa.gov/bu2/learn.html

Mission Operations
http://www.jsc.nasa.gov/bu2/MOCM.html

NAFCOM 96 Cost Model
http://www.jsc.nasa.gov/bu2/NAFCOM.html

PPI Inflation Calculator
http://www.jsc.nasa.gov/bu2/inflation/ppi/inflatePPI.html

SOCM Model
http://www.jsc.nasa.gov/bu2/SOCM/SOCM.html

Spacecraft/Vehicle Level
http://www.jsc.nasa.gov/bu2/SVLCM.html

Naval Center for Cost Analysis (NCCA)
http://www.ncca.navy.mil/links.htm

Naval Sea Systems Command (NAVSEA) Cost Engineering and Industrial Analysis
http://www.navsea.navy.mil/sea017/index.html

Parametric Cost Estimating Process Flow (Analogy)
http://www.jsc.nasa.gov/bu2/analogy.html

Parametric Cost Estimating Process Flow (CERs)
http://www.jsc.nasa.gov/bu2/CERproc.html

Resource Data Storage and Retrieval System (REDSTAR)
http://redstar.saic.com/

Unmanned Space Vehicle Cost Model
http://www.jsc.nasa.gov/bu2/PCEHHTML/pceh.htm

Software Applications

ACEIT
http://www.aceit.com/

AATe – Architectural Assessment Tool – enhanced
http://science.ksc.nasa.gov/shuttle/nexgen/AATe_Info.htm

Best Estimate
http://www.best-estimate.com/

BREAK™
http://www.protech-ie.com/break.htm

Building Systems Design SoftLink
http://www.bsdsoftlink.com/

Constructive Cost Model (COCOMO)
COCOMO II
http://sunset.usc.edu/research/COCOMOII/

COCOPRO
http://www.iconixsw.com/Spec_Sheets/CoCoPro.html

COMET
http://www.ncca.navy.mil/services/comet/index-frame.htm

COOLSoft
http://www.wwk.com/coolsoft.html

Costar
http://www.softstarsystems.com/

COSMIC
http://www.openchannelfoundation.org/cosmic/

Cost Analysis Strategy Assessment (CASA)
http://www.logsa.army.mil/alc/casa/

Cost Xpert
http://www.costxpert.com/

COSTIMATOR
http://www.costimator.com/

CostTrack
http://www.ontrackengineering.com/welcome.html

C-Risk
http://web2.deskbook.osd.mil/valhtml/2/2B/2B4/2B4S09.HTM

Crystal Ball
http://www.decisioneering.com/crystal_ball/index.html

CURV1
http://www.protech-ie.com/curv-v2.pdf

Data and Analysis Center for Software (DACS)
http://www.dacs.dtic.mil/databases/url/key.hts?keycode=4:1&islowerlevel=1

DeccaPro
http://www.deccansystems.com/DeccaPro.htm

Decision by Life Cycle Cost
http://www.ald.co.il/products/dlcc.html

Decision Tools
http://www.palisade.com/html/decision_analysis_software.html

European Space Agency Cost Modeling Software (ECOM)
http://www.estec.esa.nl/eawww/ecom/ecom.htm

European Space Agency Costing Software (ECOS)
http://www.estec.esa.nl/eawww/ecos/ecos.htm

EViews
http://www.eviews.com/

Expert Choice
http://www.expertchoice.com/

Learning Curves
http://www.simpleworks.com/LC/index.htm

Links to Software Development Resources
http://www.construx.com/reslink.htm

Logical Decisions
http://www.logicaldecisions.com/

Mainstay (Proposal Pricing)
http://www.mainstay.com/

Minitab
http://www.minitab.com/

NASA/Air Force Cost Model (NAFCOM)
http://www.jsc.nasa.gov/bu2/NAFCOM.html

Palisade
http://www.palisade.com/

@Risk
http://www.palisade.com/html/risk.html

Decision Tools Suite
http://www.palisade.com/html/decisiontools_suite.html

BestFit
http://www.palisade.com/html/bestfit.html

Precision Tree
http://www.palisade.com/html/ptree.html

Evolver
http://www.palisade.com/html/evolver.html

PRICE Estimating Suite
http://www.pricesystems.com/

Primavera Systems, Inc.
http://www.primavera.com/

Primavera Enterprise Suite
http://www.primavera.com/products/enterprise.html

Primavera Expedition Suite
http://www.primavera.com/products/expedition.html

Primavera TeamPlay Suite
http://www.primavera.com/products/teamplay.html

Prime Contract
http://www.primavera.com/products/primecontract.html

Primavera Project Planner
http://www.primavera.com/products/p3.html

SureTrack Project Manager
http://www.primavera.com/products/sure.html

REVIC
http://www.jsc.nasa.gov/bu2/PCEHHTML/pceh.htm

SEER
http://www.galorath.com/SEER_tools.html

SEER-DFM
http://www.galorath.com/ST_SEER-DFM.html

SEER-H
http://www.galorath.com/ST_SEER-H.html

SEER-IC
http://www.galorath.com/ST_SEER-IC.html

SEER-SEM
http://www.galorath.com/ST_SEER-SEM.html

SEER-SSM
http://www.galorath.com/ST_SEER-SSM.html

Small Satellite Cost Model (SSCM)
http://www.aero.org/software/sscm/

Space Operations Cost Model (SOCM)
http://www.jsc.nasa.gov/bu2/SOCM/SOCM.html

SPSS
http://www.spss.com/products/

Success4
http://www.uscost.com/success4.htm

Welcom
http://www.welcom.com/

Cobra
http://www.welcom.com/content.cfm?node=24

Colleges and Universities

Air Force Institute of Technology (AFIT)
http://www.afit.edu/

Army Logistics Management College (ALMC)
http://www.almc.army.mil/

California State University, Long Beach (Regression)
http://www.csulb.edu/~msaintg/ppa696/696regs.htm#REGRESSION

Carnegie Mellon University
http://www.cmu.edu/

Defense Acquisition University (DAU)
http://www.dau.mil/

Defense Systems Management College (DSMC)
http://www.dsmc.dsm.mil/

Federal Acquisition Institute (FAI)
http://www.gsa.gov/Portal/content/offerings_content.jsp?channelId=-13607&programId=8521&contentOID=117967&contentType=1004&cid=1

Graduate School of Logistics and Acquisition Management Cost Analysis Program
http://www.afit.af.mil/Schools/Catalog/96-97/LA/gca_courses.html

London School of Economics and Political Science (Regression)
http://econ.lse.ac.uk/ie/iecourse/notes/Sep01C2.pdf

University of Exeter (Regression)
http://www.exeter.ac.uk/~SEGLea/psy2005/simpreg.html
http://www.exeter.ac.uk/~SEGLea/psy2005/basicmlt.html

University of Hawaii (Regression)
http://www.soest.hawaii.edu/wessel/courses/gg313/DA_book/node74.html

University of Michigan (Learning Curves)
http://ioe.engin.umich.edu/ioe463/learning.pdf

University of Southern California (Regression)
http://www-rcf.usc.edu/~moonr/econ419/econ414_2.pdf

University of Sussex (Regression)
http://www.cogs.susx.ac.uk/users/andyf/teaching/pg/regression1/sld001.htm

Other Government Websites

Department of the Treasury
http://www.ustreas.gov/

e-Government
http://egov.gov/

Federal Acquisition Regulation (FAR)
http://www.arnet.gov/far/

General Accounting Office (GAO)
http://www.gao.gov/

Office of Management and Budget (OMB)
http://www.whitehouse.gov/omb/

Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics
www.acq.osd.mil/

United States Government Standard General Ledger (USSGL)
http://www.fms.treas.gov/ussgl/index.html

Technical Papers

NASA Technical Report Service
http://www.jsc.nasa.gov/bu2/NTRS.html

RAND Reports
http://www.rand.org/publications/search.html

The Standish Group CHAOS Reports
http://www.pm2go.com/

Magazines

Controller Magazine (Business Finance)
http://www.businessfinancemag.com/

Fast Company
http://www.fastcompany.com/

Federal Employee's News Digest

http://www.fendonline.com/

Government Executive
http://www.govexec.com/

Newsletters

The Critical Path Newsletter
http://fpd.gsfc.nasa.gov/news.html

NASA Procurement Countdown
http://www.hq.nasa.gov/office/procurement/cntdwn.html

NASA Procurement Policy News
http://ec.msfc.nasa.gov/hq/library/policy1.html

Other Research Tools

DoD Dictionary
http://www.dtic.mil/doctrine/jel/doddict/

NASA Earth Science Glossary
http://gcmd.gsfc.nasa.gov/Aboutus/sitemap.html

NASA Glossary of Financial Terms
http://www.jsc.nasa.gov/bu2/glossary.html

Project Management Glossary
http://www.maxwideman.com/pmglossary/index.htm

SCEA Glossary
http://www.sceaonline.net/

WorldWideWeb Acronym and Abbreviation Server
http://www.ucc.ie/acronyms/

D. NASA Organizational Charts

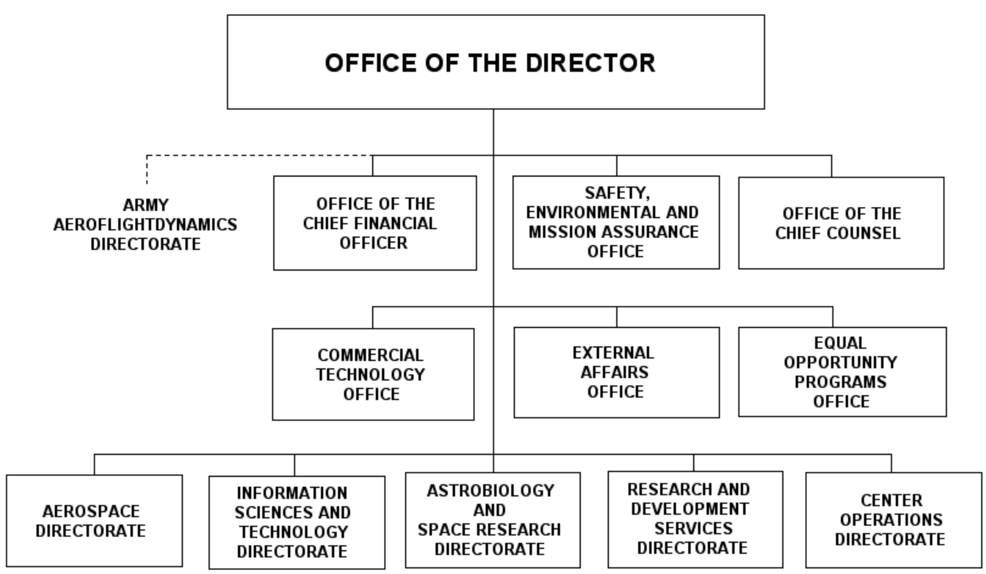
This Organizational Chart Appendix includes charts from all NASA Centers and the entire NASA organization. For more detailed information please refer to the NASA Procedures and Guidelines (NPG) 1000.3. This NPG includes detailed information on the entire NASA organization, including mission statements, responsibilities, special relationships, and lines of succession.

NASA Centers	SMO/Chief Engineer	CFO	Center Operations
NASA Headquarters			
LaRC IPAO	X		
ARC		X	
DFRC			
GRC		X	
GSFC	X		
JPL	X		
JSC	X		
KSC	X		
MSFC	X		
SSC			X

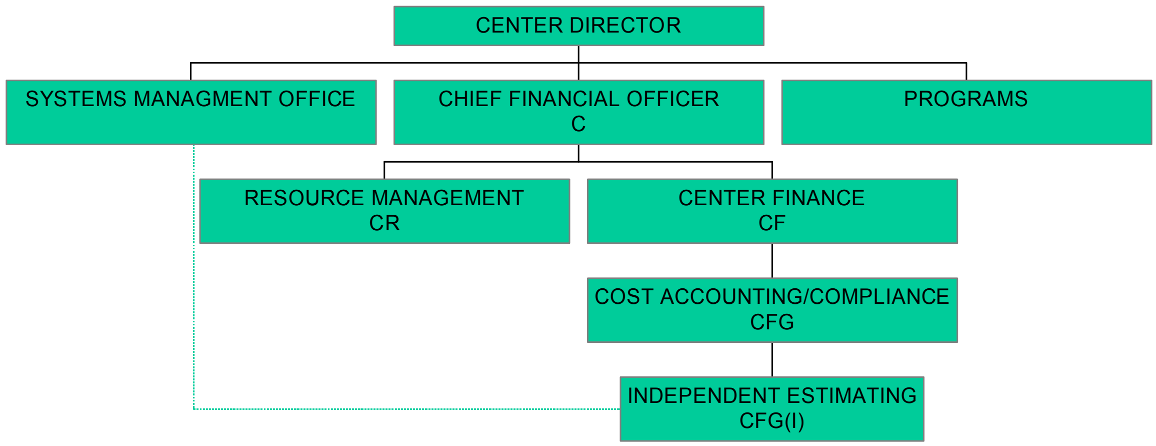
NASA CEC Functional Organization Structure

NASA Organizational Chart

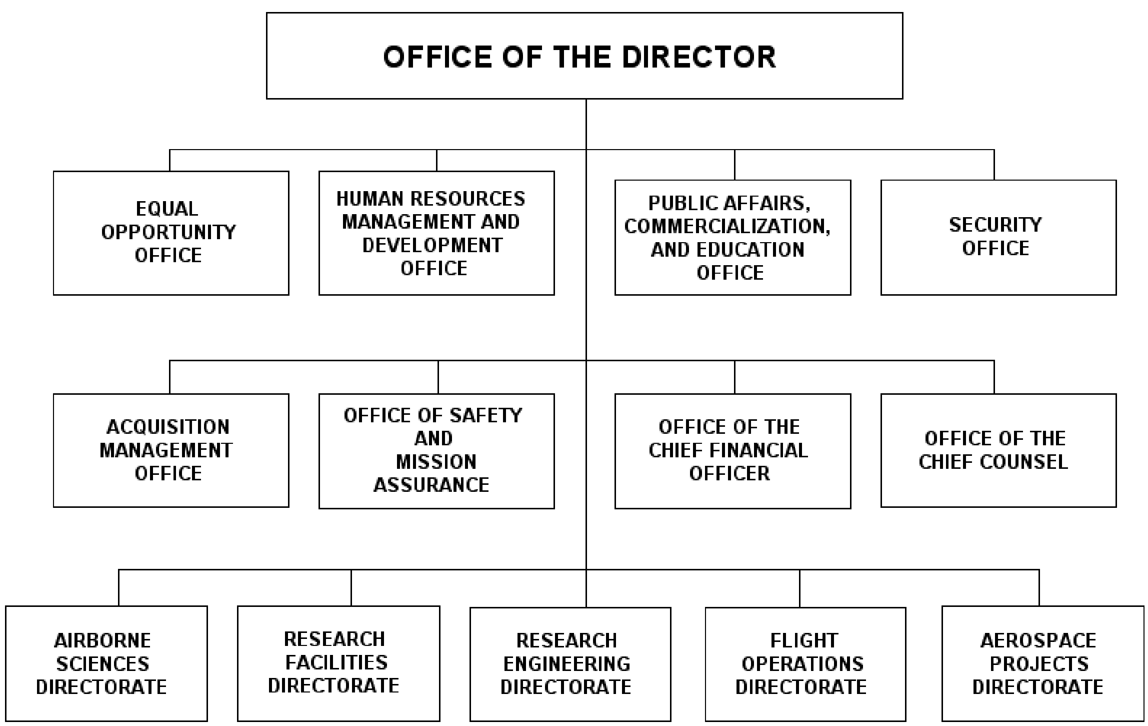
Ames Research Center Organizational Chart



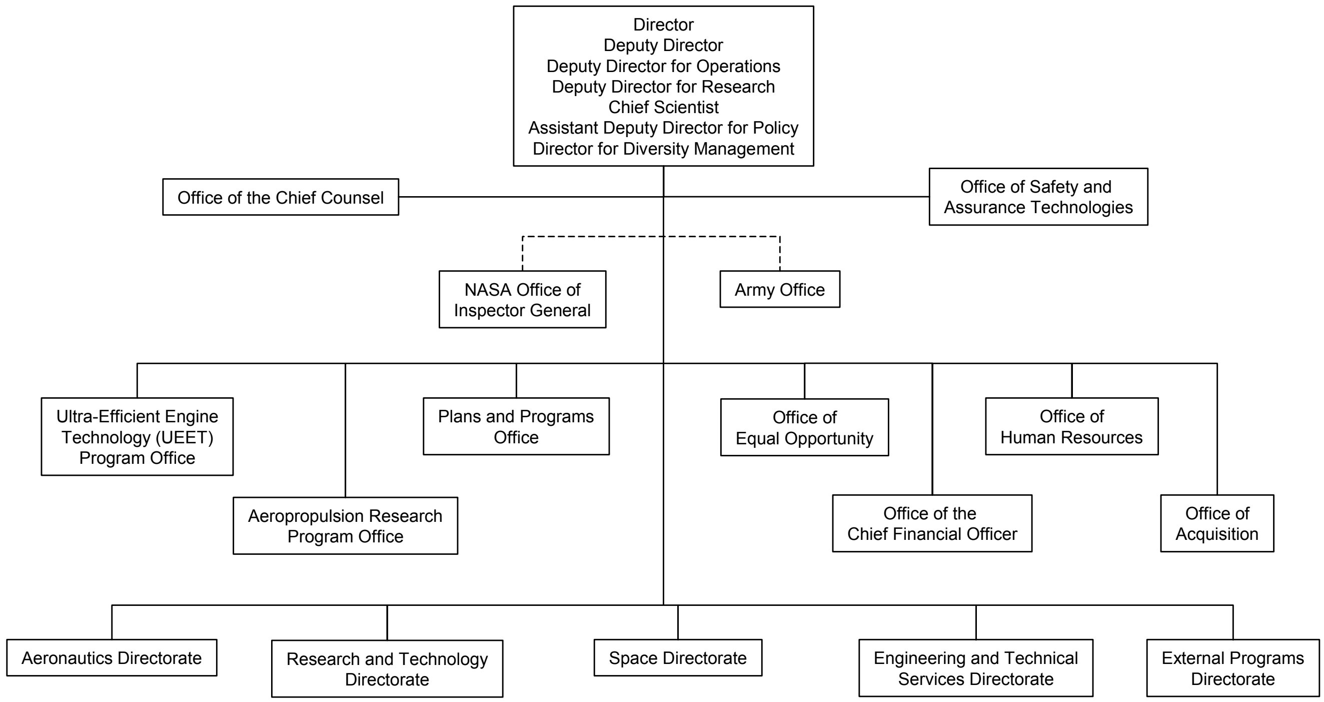
Ames Research Center Independent Cost Estimating Organizational Chart



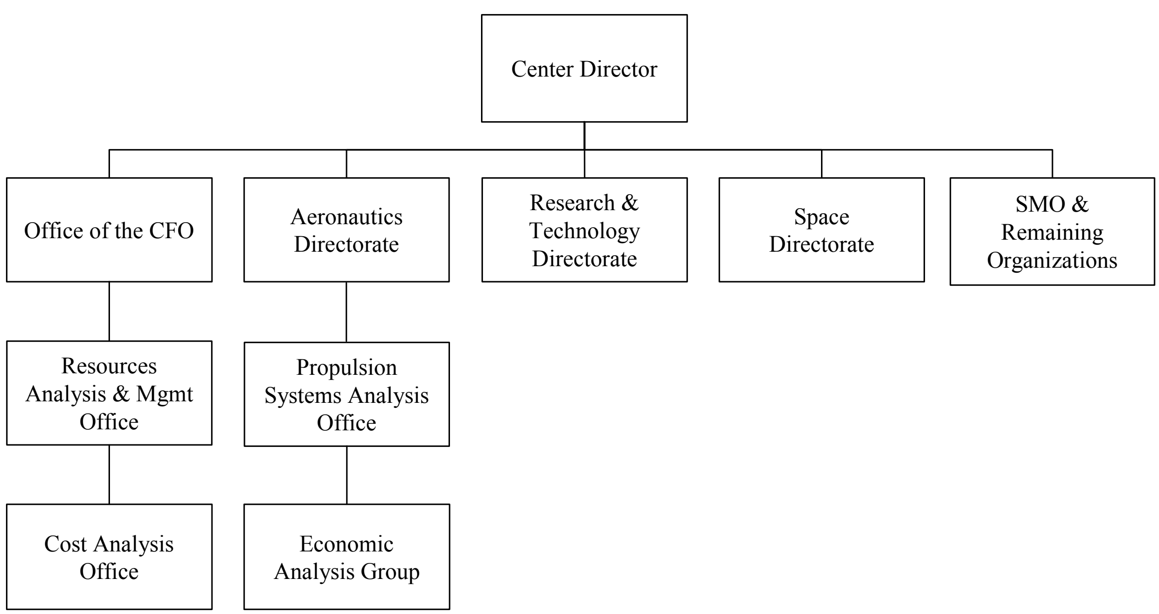
Dryden Flight Research Center Organizational Chart



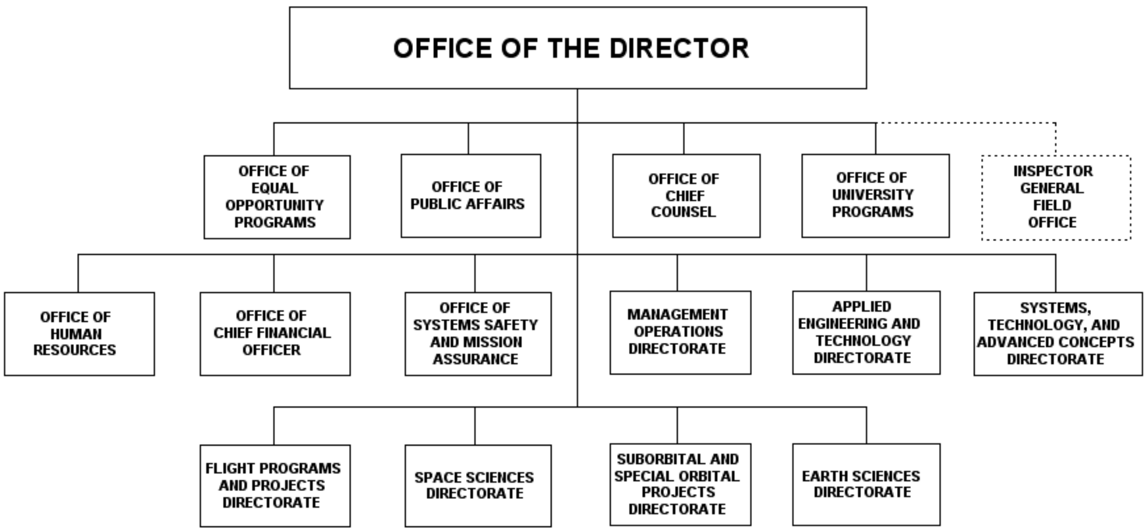
Glenn Research Center Organizational Chart



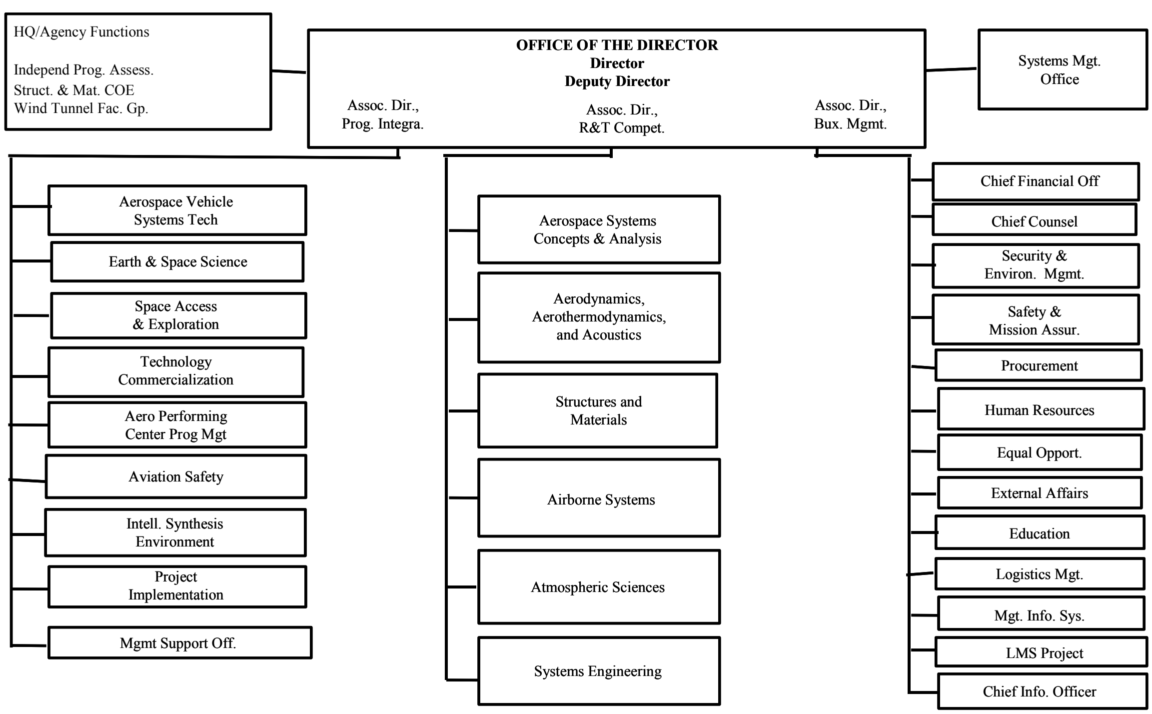
Glenn Research Center Cost and Economic Analysis Organizational Chart



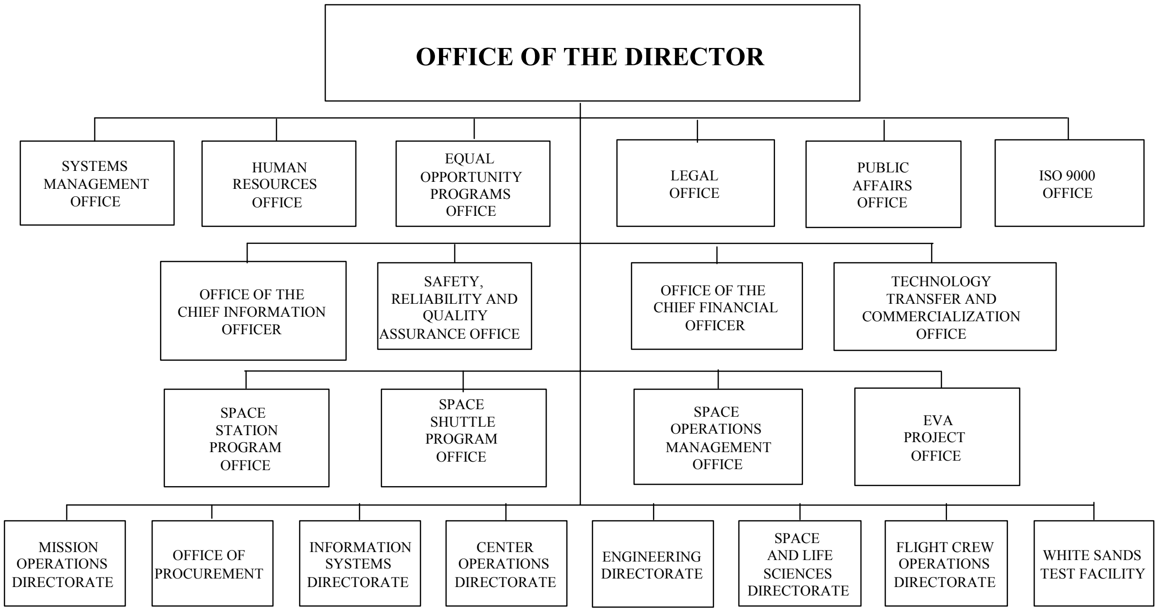
Goddard Space Flight Center Organizational Chart



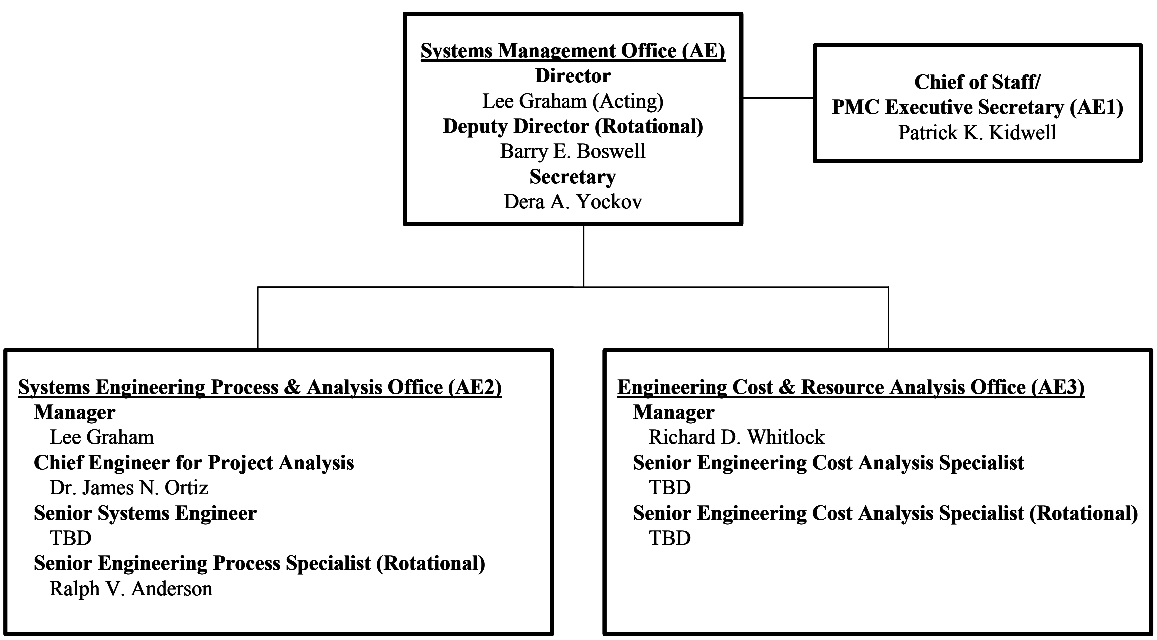
Langley Research Center Organizational Chart



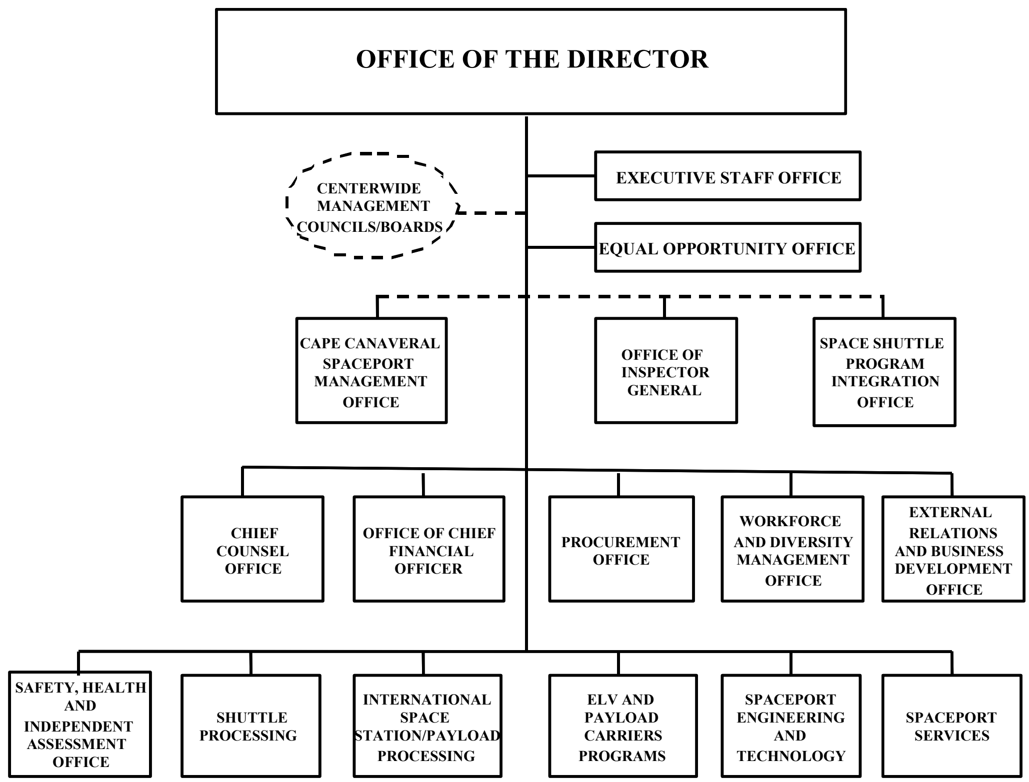
Johnson Space Center Organizational Chart



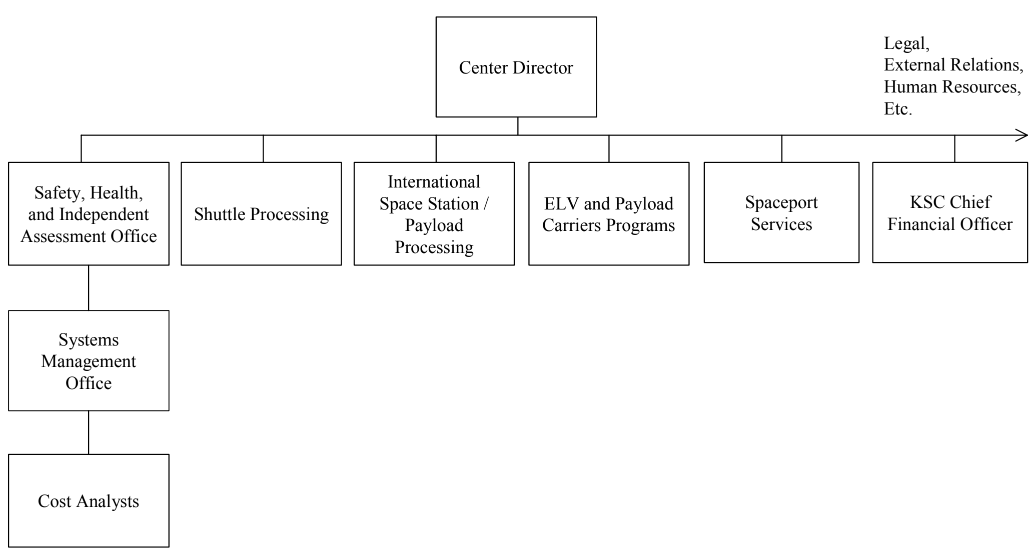
Johnson Space Center Systems Management Office (SMO) Organizational Chart



Kennedy Space Center Organizational Chart



Kennedy Space Center Cost Analysts Organizational Chart



Marshall Space Flight Center Organizational Chart

OFFICE OF THE DIRECTOR

- SAFETY & MISSION ASSURANCE OFFICE
- PROCUREMENT OFFICE
- OFFICE OF CHIEF COUNSEL
- OFFICE OF CHIEF FINANCIAL OFFICER
- INSPECTOR GENERAL FIELD OFFICE
- EQUAL OPPORTUNITY OFFICE
- SPACE SHUTTLE PROJECTS OFFICE
- SYSTEMS MANAGEMENT OFFICE
- SPACE TRANSPORTATION DIRECTORATE*
- SCIENCE DIRECTORATE
- FLIGHT PROJECTS DIRECTORATE
- ENGINEERING DIRECTORATE
- CENTER OPERATIONS DIRECTORATE
- CUSTOMER AND EMPLOYEE RELATIONS DIRECTORATE

*Managers of Lead Center Programs report to Center Director

Marshall Space Flight Center Engineering Cost Office Organizational Chart

VS01

SYSTEMS MANAGEMENT OFFICE (SMO)

OFFICE OF THE DIRECTOR

Axel Roth, Acting Director

William H. Nabors (Rip) (Asst. Center Export Control Administrator)
George M. Kozub (Export Control)
Vanita B. Brown (Export Control)
Helen P. Eddleman (Management Analyst)

VS10

Systems Engineering Office

Gerald Flanagan (Gerry), Manager

John W. Brunson
Michelle B. DeLay (Shelley)
Richard F. Gladwin (Rich)
Patrick B. McDuffee (Pat)
Robert L. McKemie (Bob)
Stephen F. Newton (Steve)
Neil E. Rainwater

Contractor Support Onsite

VS20

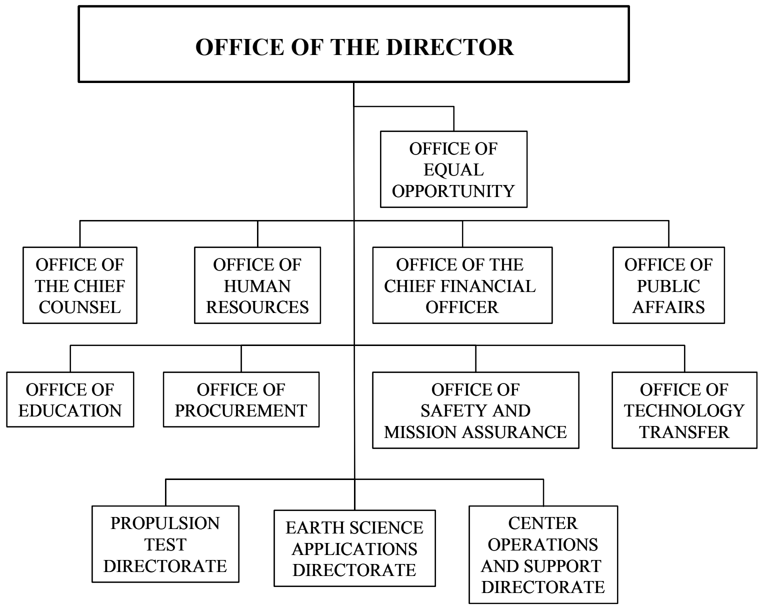
Engineering Cost Office

Joseph W. Hamaker (Joe), Manager

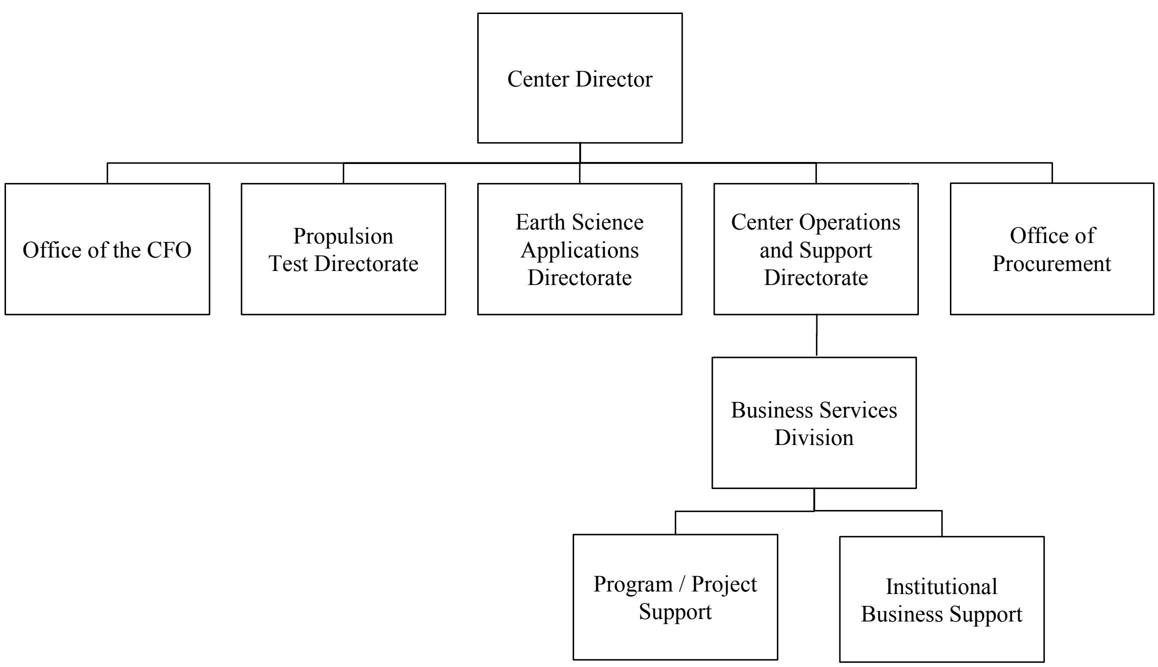
Carol A. Lovell (MSA)
Spencer M. Hill
Myron S. May (Scott)
Mahmoud R. Naderi
Frank A. Prince (Andy)
Linda A. Shackelford
Eric J. Shaw
Robert B. Shepard
Barbara A. Stone-Towns
Michael E. Vanhook (Mike)
Charles Hunt (Co-op)

Updated 02/2002

Stennis Space Center Organizational Chart



Stennis Space Center Business Services Organizational Chart



E. Cost Estimating Working Group (CEWG)

The purpose of the CEWG is to strengthen NASA's cost estimating standards and practices by focusing on improvement in tools, processes, and resources (e.g., training, employee development). Membership is comprised of senior cost estimating analysts from each NASA Center. The working group is also a forum to foster cooperation and interchange in areas such as sharing models and data across Centers and implementing "lessons learned". The CEWG meets three times a year at different NASA locations. The IPAO serves as the Chair of the CEWG.

The CEWG also sponsors the annual NASA Cost Symposium Workshop which focuses on providing an opportunity for all NASA cost estimators, including support contractors, to present technical briefs on topics such as the status of cost model development, case studies, lessons learned, and other cost analysis research areas. A recent Point of Contact list for the CEWG is located below.

NASA Center	Name	E-mail address	Phone Number	Fax Number
ARC	Charlotte Y. DiCenzo	Cdicenzo@mail.arc.nasa.gov	(650) 604-5297	(650) 604-1191
GRC	Bob Sefcik	Robert.J.Sefcik@grc.nasa.gov	(216) 433-8445	(216) 433-3940
GSFC	Dedra Billings	dbilling@pop100.gsfc.nasa.gov	(301) 286-6380	(301) 286-0312
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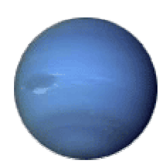
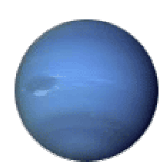


F. NASA Cost Analysis Improvement Plan

NASA COST ANALYSIS IMPROVEMENT PLAN 1999

INDEPENDENT PROGRAM ASSESSMENT OFFICE
LANGLEY RESEARCH CENTER
HAMPTON, VA



ABSTRACT

The need to improve the quality and accuracy of cost estimates of proposed new aerospace systems has been widely recognized. The industry has done the best job of maintaining related capability with improvements in estimation methods and giving appropriate priority to the hiring and training of qualified analysts. Some parts of Government, and National Aeronautics and Space Administration in particular, continue to need major improvements in this area. Recently, NASA recognized that its cost estimation and analysis capabilities had eroded to the point that the ability to provide timely, reliable estimates was impacting the confidence in planning many program activities. As a result, this year the Agency established a lead role for cost estimation and analysis. The Independent Program Assessment Office located at the Langley Research Center was given this responsibility.

This paper presents the plans for the newly established role. Described is how the Independent Program Assessment Office, working with all NASA Centers, NASA Headquarters, other Government agencies, and industry, is focused on creating cost estimation and analysis as a professional discipline that will be recognized equally with the technical disciplines needed to design new space and aeronautics activities. Investments in selected, new analysis tools, creating advanced training opportunities for analysts, and developing career paths for future analysts engaged in the discipline are all elements of the plan. Plans also include increasing the human resources available to conduct independent cost analysis of Agency programs during their formulation, to improve near-term capability to conduct economic cost-benefit assessments, to support NASA management's decision process, and to provide cost analysis results emphasizing "full-cost" and "full-life cycle" considerations.

The Agency cost analysis improvement plan has been approved for implementation starting this calendar year. Adequate financial and human resources are being made available to accomplish the goals of this important effort, and all indications are that NASA's cost estimation and analysis core competencies will be substantially improved within the foreseeable future.

Introduction

Everyone knows that the enemy of approval and start up of new programs is the cost analyst who has accurate estimation tools and a desire to deliver an honest estimate of what the program will really cost. The estimator is the person who develops program costs that exceeds budget availability, makes the program less competitive with other programs competing for limited resources, and often forces the program to focus on objectives somewhat less than desirable. Right? No, that is not exactly the way good management is supposed to work. A responsible program/project manager should consider a reliable cost estimate as a resource available for assuring management success.

Included in the primary reasons why many of today's aerospace program managers eventually find themselves in trouble are:

Before program approval, they may not have adequately defined (systems engineered) the system they planned to develop and operate. This includes developing a full understanding of technical and programmatic risks that can be barriers to success,

They may not have developed a reliable estimate of what it will cost to successfully complete the program, and

They may accept the job of managing the program with a budget (and maybe schedule) with little or no relation to the expected actual cost of the program.

So, what's so difficult? Why can't responsible program management correct these deficiencies and more often than not, deliver the program product within budget and on schedule? A primary requirement for success is the program manager wanting to be "responsible," and a second requirement is the program manager having the resources to complete quality, up-front systems engineering and to secure a reliable cost estimate.

This paper will not attempt to address the adequacy of systems engineering tools or other resources needed by the program manager. Much has been recently written about efforts to improve tools used in systems engineering, both in the United States and other countries. Of particular interest is the Intelligent Synthesis Environment Program of NASA Langley (reported at last year's IAF Congress, Reference 1) with objectives to advance the state-of-the-art in near- and far-term analysis/design tools and promote collaborative engineering among engineering organizations. Providing reliable cost estimates (the focus of this paper) is a subject that has received less attention. Reliable cost estimation, as a resource to the program manager, has become a scarce commodity, at least in NASA. In addition, the image of the cost estimator, as the enemy to program approval, is wrong. Hopefully, what follows will show that NASA recognizes the value that reliable cost estimation brings to the program formulation and approval process.

Before turning to how NASA is correcting deficiencies in its program cost estimation capabilities, it may be helpful to define "cost estimation" as used in the following discussion. For the purpose of this definition, and for other discussions in this paper, "program" refers to an activity involving the development and operation of a hardware system, or more specifically perhaps, a space system. Cost estimation is the process of analyzing each hardware element, the buildup, integration and test of these elements, and the operation of the system over some specified life-cycle (including disposal of the asset), with respect to the cost associated with the total effort. The analysis uses analysis tools, or models, that relate hardware elements, complexity, and risks of failure to expected costs – a parametric analysis. Parametric estimation involves the development and utilization of cost estimation relationships between historical costs and program, physical, and performance characteristics. The basic premise is that the cost of a system, such as a spacecraft, is related in an approximate, but quantifiable way, to a physical characteristic such as weight, pointing accuracy, number of parts, or other attribute.

There may be at least two different types of cost estimates, an “advocacy” estimate and an “independent” estimate. An advocacy estimate may be derived by program management, and as such, may be skewed in ways beneficial to successful program advocacy. An independent cost estimate is derived by one disassociated with the program, and therefore, not encumbered by the pressures of advocacy and free to be objective – “tell it like it is.” Further, the cost estimation and analysis (CEA) competency is defined as the total capability of an organization to provide the cost estimates required by the organization for budget planning and execution, and program planning and approval.

Background

NASA, at one time, maintained a respectable CEA competency. Qualified cost analysts were employed across the NASA Centers with appropriate skills and in numbers to support the Agency's needs. Several related situations resulted in the Agency losing much of its recognized competency:

1) The Agency never recognized CEA as a discipline as important as other professional disciplines needed for systems engineering and development. There was never a "career path" available to those responsible for CEA, so possibilities for career advancement were always in doubt. As a result, often other career opportunities looked more promising and qualified analysts left the work area.
2) Declining budgets, increasing competition for limited funds, and other institutional considerations, tended to lead many parts of the Agency to underestimate program development and operations costs. It became obvious that estimators were too involved in the advocacy of the programs. The appearance of objectivity in the CEA process was in question.
3) Declining workforce led to the establishment of hiring priorities that limited the replenishment of CEA talent. In addition, limited budgets forced drastic reductions in investments that would lead to upgrading the Agency's CEA tools and state-of-the-art analysis capabilities.

In the early 1990s, several outside advisory groups began to recognize the declined state of the NASA CEA competency. Of particular importance was the Presidential Commission on the Future of Space (Reference 2), more commonly known as the Augustine Committee. The Commission recommended to NASA that "an exceptionally well-qualified, independent cost analysis group be attached to headquarters with ultimate responsibility for all top-level cost estimating, including cost estimates provided outside of NASA." As a complementary recommendation to foster the independent assessment of new proposed programs of NASA, the Commission also recommended the establishment of an independent "systems concept and analysis group reporting to the Administrator."

It was in the 1993 time period that the Agency formed a cost analysis group in the Headquarters Office of the Chief Financial Officer. This group was also given the responsibility to organize and conduct Independent Annual Reviews (IAR) of the progress of Agency programs and report findings to the Agency Program Management Council. This action recognized that independent cost analysis and the development of dependable estimates were of critical importance to NASA. About 4 years later, at the insistence of the NASA Advisory Committee, the Independent Program Assessment Office (IPAO) was formed at the NASA Langley Research Center. The IPAO provides Independent Assessments (IA) of new programs, and reports findings and recommendations related to the approval of programs to the Office of the Administrator. The responsibility for the Independent Annual Reviews was transferred to the IPAO at that time. With the formation of the IPAO, the cost estimation function previously established all but disappeared, except for a small number of cost analysts that joined the IPAO at Langley to continue cost analysis to support the review and assessment activities.

During the period from the mid-1980s to the present, for the reasons stated earlier, there was a greater than 50 percent attrition in the NASA CEA competency. At present, the Agency of over 18,000 people employs less than 25 full-time, career cost analysts. In addition to the inability to develop sufficient cost information for management of its programs, there is concern for the Agency's ability to adhere to Federal standards in this area. The various remaining elements of the cost community are decentralized and have ambiguous roles and responsibilities. There is ineffective use and limited sharing of these resources, and there is no clear definition of a professional cost estimation competency.

The Agency currently conducts systems engineering, budget development, and cost estimating separately. There is inconsistent use of cost estimating techniques and tools, and there are outdated tools and cost databases. During program planning, program requirements and risks to program success are not adequately defined, and usually, no program life-cycle costs are considered in the approval process. Cost analysis tools are insufficient for estimating program cost for programs that are to be conducted with "new ways of doing business" or "faster, better, cheaper."   And to add to these deficiencies, budget-driven processes often are unsupported by CEA.

The Federal Office of Management and Budget (OMB) is pushing for improved cost analysis prior to budget submission. The OMB goals include better schedule and performance goals, more realistic baseline cost, the inclusion of independent cost estimates, and full life-cycle cost, cost benefit, and estimate of risk and uncertainty. All these cost considerations should be used as a basis for selecting future NASA programs.

Lastly, in recognition of the above deficiencies, the Administrator recently directed improvements in NASA's independent cost estimation abilities. His direction resulted in the assignment to the IPAO this year the Agency lead responsibility to correct the deficiencies and restore the Agency's cost estimation and analysis competency. The following discussion details the plans to fulfill the new IPAO role.

Overall Strategy

With the assignment of the lead role for cost estimation and analysis to the IPAO, the primary responsibility of the Office will be the reconstitution of a comprehensive, core CEA competency for the Agency. This responsibility includes the development of a CEA strategic plan for the accomplishment of the role, providing leadership for the establishment of an adequately staffed and skilled NASA cost estimating community, and rallying the community in a coordinated effort to eliminate the cost estimation deficiencies currently plaguing the Agency. The IPAO, NASA Headquarters, and the NASA Centers will work together toward implementation of state-of-the-art costing capabilities including investing in new and upgraded tools, and organizing appropriate training. The Office will function as an independent Agency resource for program, Center, and Enterprise management by providing independent cost estimates to support program planning and implementation.

Goals

The overall goal of the lead CEA activity is to prepare NASA for the future by restoring the ability to develop accurate, reliable cost estimates of the Agency's programs and provide confidence for senior leadership that NASA's programs are based on a solid foundation of understanding cost and risk. The new CEA core competency created will involve state-of-the-art business practices for a full spectrum of cost analysis tools and processes for managers and assure integration of cost estimating, systems engineering and management, and budget development. Cost estimates will be timely, and a better understanding of risk and schedule issues will be developed prior to program approval.

Specific examples of CEA competency improvement goals include making the following changes in the way NASA derives its program cost information:

1. Traditional, non-integrated tools will be replaced by state-of-the-art, integrated tools.
2. Center oriented cost organizations will become part of an intra-Agency cost community.
3. Functionally focused cost tasks will transition to integrated product teams that include estimating professionals.
4. Non-professional "journeymen" cost analysts will be trained and matured into core competency cost analysts.
5. Non-full cost estimates will be substituted with full cost estimates.
6. Center oriented tools will become shared Agency tools.
7. Separate development and operational costs estimates will be replaced by integrated, full life-cycle estimates.

The focus of the CEA improvement initiative will be on people, tools, organization, and processes.

People

The most important resources in any activity are the people involved. For success, the people must be competent, motivated, and have the other resources (tools, money, etc.) to get the job done. As stated earlier, NASA is short of properly skilled cost analysis workforce. Therefore, attention to the "people" factor becomes a first-order priority of the NASA CEA improvement initiative.

Adequate compensation is a genuine motivator, but it is well known that when one decides to work in the public sector, there are limits to what one can expect in terms of pay. Therefore, there must be other motivators that cause an employee to want to make a career in government. With respect to those working in the CEA field, for example, expectations of being treated as a valued employee with definite opportunities for professional growth is a true plus. Unfortunately, in NASA, there has not existed much of a professional career path. In fact, while systems development activities require a wide variety of professional disciplines to implement the program, the activities also require CEA, but CEA is not viewed as a discipline in the same way as other areas (such as the engineering disciplines). A primary goal of the initiative is help establish CEA as a recognized professional discipline with a formal growth ladder and opportunities for senior level positions for individuals dedicated to the area. The IPAO will work with NASA's human resource organizations to help develop this potential.

The IPAO will assist the NASA Centers in recruiting new employees to the Agency's core competency of CEA. A database of qualified individuals with interest in working for NASA in this area will be maintained, and as a Center wishes to supplement or replenish its CEA staff, the Office will offer appropriate assistance in seeking qualified applicants. The Office will also work with the Agency's career training organizations to help develop CEA-related training opportunities for the staff. This should include various professional and leadership training as well as specific training in the CEA discipline to improve the individual's skills. In addition, the IPAO will help develop Agency-wide on-the-job training that will improve professional development while creating opportunities for inter-Center exposure and cross-fertilization of CEA methods among Centers.

Lastly, the IPAO will invest in the development of a college undergraduate course on CEA. It is interesting that in an environment of economic pressure, constant push to reduce cost, and to build systems "faster, better, and cheaper," we graduate engineers without a notion of how much it costs to build the systems they are trained to design. The course will be designed with the objective of introducing college engineering students to cost analysis, and will be offered to any engineering school desiring to improve its engineering curriculum in this regard. If an appropriate one can not be found, there is some thought currently being given to the development of an undergraduate-level text on the subject of CEA for the purpose of aiding in the teaching of the course.

Tools

NASA must be capable of generating responsive, reliable, quality cost estimates of future missions (such as Mars Exploration) that involve the use of new technologies and innovative approaches or concepts for satisfying mission objectives. In order to achieve this capability, the IPAO will be responsible for advancing the state-of-the-art in cost models and analytical tools. One of the first capabilities identified for immediate development is the integration of systems development cost models with operations cost models. Efforts are underway to integrate the Space Operations Cost Model (SOCM), Reference 3, which is an internally developed model, with several commercial models such as the NASA/Air Force Cost Model (NAFCOM) and the PRICE Cost Model.

There are on-going discussions within the CEA community about the requirements of the next generation of NASA cost models. In the near future, NASA management will require "full cost" estimates, estimates that include the workforce, general & administrative costs, facility, and program/project costs. Models to estimate workforce cost are being developed to meet this requirement along with other methodologies to estimate the full cost of NASA projects. The NASA Integrated Financial Management System, currently being developed elsewhere in NASA, will assist in providing the CEA discipline with the full cost accounting data needed to develop full cost estimates. Also, models will be required to more accurately determine the cost impact of new systems development approaches such as "faster, better, cheaper."

The Intelligent Synthesis Environment (ISE) program is a NASA initiative to develop a virtual reality design environment. The goal is an advancement of the simulation based design environment involving the integration of design and cost models with analytical tools using intelligent systems technology. As a result of this new environment, the time to develop new system designs and to estimate the costs will be greatly reduced. IPAO will be collaborating with the ISE program, specifically with the Cost and Risk Management Technology element of ISE, to develop cost and risk models that work within the ISE environment. These cost models must be capable of reflecting the revolutionary reduction in the time and cost of various phases of the design cycle and be state-of-the-art tools. Among the analytical tools planned for development is an improved schedule assessment tool.

IPAO will lead NASA's participation in the establishment of joint tool development efforts with other government and private industry cost analysis organizations. Recently, NASA became a member of the newly established Consortium on Space Technology Estimating Research (CoSTER) organization. The CoSTER includes most of the government agencies with an interest in space. This relationship will likely result in joint tool development investments that will benefit a broader range of government organizations. In addition, there will be efforts to assure cost model training opportunities are made available to all cost analysts. The result of CEA tool investments will be powerful cost-, schedule-, and risk-estimating systems that help NASA better understand the cost of doing business and make the right management decisions.

Organization

The IPAO will carry out its CEA responsibilities with active participation of all NASA Centers and Headquarters. The Agency-wide initiative includes the creation of a CEA Steering Group with members representing all the cost estimation organizations across NASA. This group is actively involved in establishing overall goals of the initiative, in decisions affecting the future of the CEA competency, in defining workforce and analysis tool requirements, and in the implementation of the initiative's elements. Group members represent the CEA-related interests of their home Centers, serve to share experiences (or lessons-learned) from cost analysis activities, and accept complementary responsibilities for various initiative actions. In addition, the group will facilitate an Agency-oriented CEA culture rather than a specific Center-oriented culture.

The IPAO, in cooperation with the CEA Steering Group, is organized to serve the Agency in several important ways. It is a primary interface with other government agencies to coordinate inter-Agency CEA activities, perform completely independent, non-advocate cost estimates in support of program formulation, and provide other CEA support to Centers when Center resources are insufficient. For the CEA initiative, the IPAO workforce was increased by eight, and sufficient funds have been provided to secure contracted CEA analysis to meet support demands. In addition to the IPAO, it is expected that the Centers' CEA organizations will also be appropriately expanded to meet the cost analysis requirements unique to each Center.

The IPAO CEA responsibilities include serving as the voice of the Agency's cost estimation and analysis community. The Office will integrate the fragmented concerns of 10 NASA Centers into focused CEA community concerns and issues, and this consolidation will enable the community's voice to be much stronger than each Center acting separately. It is expected that this will result in more positive results in efforts to resolve the overall CEA competency deficiencies.

Processes

Since one of the responsibilities of the IPAO in the CEA initiative is to oversee the quality control of the Agency's CEA products, the Office will be working to create standards for the discipline and to have all Center "buy-in" to the standards. The main focus on creating standards will be to ensure that CEA processes are consistent and conform to the best business practices, provide timely and accurate cost estimates, and are of maximum value to the Agency. The CEA Steering Group will lead in the development of the standards, and it is expected that all processes will be subject to ISO certification. Included in the processes will be guidelines for cost analysts' continued participation through the project's life and being involved in the creation of full-cost estimates of the system development, operation, and disposal. A closer relationship between those responsible for developing systems requirements and those responsible for estimating requirement's cost must be developed. The full integration of CEA into design activities is necessary. Cost analysts must be active participants in initial system trade studies that should be conducted to derive the system approach that achieves the requirements in the most cost-effective way. In today's program management world, the cost analyst must remain an active, but objective member of the team throughout the entire life-cycle of the program.

Summary

The IPAO led CEA initiative will focus on up-front planning and continued improvement of the NASA CEA competency and will provide key benefits to the future systems development activities of the Agency. These benefits include the following:

4) A new cost estimating culture and an integrated cost community that better serves the Agency.
5) Enhanced costing skill and a professional career path for analysts.
6) Better definition of systems development and operational risks and an estimate of the costs to mitigate these risks.
7) Reliable, responsive, full life-cycle cost estimates.
8) Cost estimate quality control.
9) Continual CEA support throughout project life-cycle.
10) Databases for improved cost estimating and cross program analysis.
11) State-of-the-art, user-friendly tools and processes that accommodate NASA's new ways of conducting systems development activities.
12) Make the Agency more OMB-compliant.
13) Better fiscal support and budget defense

The IPAO, in its lead role for CEA, will function as an independent Agency-level resource and will ensure all Centers are involved in the reconstitution of this most important Agency discipline. The bottom line is that after these changes are instituted, both the Agency and those in charge of NASA's appropriations will have a much greater confidence that our proposed costs will also be our actual costs. This will make our budgets more defensible, leading to better Congressional support.

References

1. Monell, Donald W. and Piland, William M., "Aerospace Systems Design in NASA's Collaborative Engineering Environment," IAF Paper 99.U.1.01, October 1999.
2. Augustine, N., "Report of the Advisory Committee on the Future of the U.S. Space Program," 1990.
3. Moore, Arlene, Proceedings of the International Society of Parametric Analysts, "Parametric Prospectives in the Information Age," New Orleans, May 1997.

G. NAFCOM WBS

Generic NAFCOM WBS for a Manned, Two-Stage Launch Vehicle

WBS Element
1.0 Two-Stage Vehicle (manned)
1.1 Stage 1 (reusable)
1.1.1 Stage 1 Subsystems
1.1.1.1 Structures & Mechanisms
1.1.1.1.1 Vehicle Structures & Mechanisms
1.1.1.1.2 Tank Structures & Mechanisms
1.1.1.2 Thermal Control
1.1.1.2.1 Environment/Active Thermal Control
1.1.1.2.2 Induced Thermal Protection
1.1.1.2.3 Tank Thermal Control
1.1.1.3 Reaction Control System
1.1.1.4 Main Propulsion System (less engines)
1.1.1.5 Electrical Power and Distribution
1.1.1.6 Command, Control & Data Handling
1.1.1.7 Guidance, Navigation and Control
1.1.1.8 Landing System
1.1.1.9 Liquid Rocket Engine
1.1.1.10 Turbojet
1.1.2 Stage 1 System Integration
1.1.2.1 Integration, Assembly and Checkout (IACO)
1.1.2.2 System Test Operations (STO)
1.1.2.3 Ground Support Equipment (GSE)
1.1.2.3.1 Tooling
1.1.2.3.2 M/E GSE
1.1.2.4 System Engineering & Integration (SE&I)
1.1.2.5 Program Management (PM)
1.1.2.6 LOOS
1.2 Stage 2 (reusable)
1.2.1 Stage 2 Subsystems
1.2.1.1 Structures & Mechanisms
1.2.1.1.1 Vehicle Structures & Mechanisms
1.2.1.1.2 Tank Structures & Mechanisms
1.2.1.2 Thermal Control
1.2.1.2.1 Environment/Active Thermal Control
1.2.1.2.2 Induced Thermal Protection
1.2.1.2.3 Tank Thermal Control
1.2.1.3 Reaction Control System
1.2.1.4 Orbital Maneuvering System
1.2.1.5 Main Propulsion System (less engines)
1.2.1.7 Electrical Power and Distribution
1.2.1.8 Command, Control & Data Handling
1.2.1.9 Guidance, Navigation and Control
1.2.1.10 Landing System
1.2.1.11 Liquid Rocket Engine
1.2.2 Stage 2 System Integration
1.3 CTV (crew and cargo)
1.3.1 CTV Subsystems
1.3.1.1 Structures & Mechanisms
1.3.1.2 Thermal Control
1.3.1.2.1 Enviroment/Active Thermal Control
1.3.1.2.2 Induced Thermal Protection
1.3.1.3 Propulsion
1.3.1.5 Reaction Control Subsystem
1.3.1.6 Electrical Power and Distribution
1.3.1.7 Command, Control & Data Handling
1.3.1.8 Guidance, Navigation and Control
1.3.1.9 Environmental Control and Life Support
1.3.1.10 Crew Accommodations
1.3.1.11 Recovery and Auxiliary System
1.3.1.12 Landing System
1.3.1.13 Liquid Rocket Engine
1.3.2 CTV System Integration
1.3.2.1 Integration, Assembly and Checkout (IACO)
1.3.2.2 System Test Operations (STO)
1.3.2.3 Ground Support Equipment (GSE)
1.3.2.3.1 Tooling
1.3.2.3.2 M/E GSE
1.3.2.4 System Engineering & Integration (SE&I)
1.3.2.5 Program Management (PM)
1.3.2.6 LOOS

Sample WBS extracted from Appendix C of the JPL Formal Cost Estimation Procedure (JPL D-16376).

Project Design and Development Phase	
1.0	Project Management
1.1	Project Manager and Staff
1.2	Administration and Control
1.3	Mission Assurance
1.4	Outreach
2.0	Science
2.1	Science Investigators
2.2	Science Teams
2.3	Science Analysis
3.0	Project and Mission Engineering
3.1	Project Engineering
3.2	Mission Analysis
3.3	Launch Approval
4.0	Payload
4.1	Payload Management
4.2	Payload Engineering
4.3	Instruments
4.4	Instrument I&T Support
5.0	Spacecraft
5.1	Spacecraft System Management
5.2	Spacecraft System Engineering
5.3	Subsystems
5.3.1	Attitude Control
5.3.2	Command & Data
5.3.3	Telecommunications
5.3.4	Power
5.3.5	Propulsion
5.3.6	Structures, Mechanisms, Cabling
5.3.6.5	S/C Mechanical Buildup
5.3.7	Thermal Control
5.3.8	Software
5.3.9	Launch Vehicle Adapter
5.3.10	Other
5.4	Spacecraft Contract Management
5.5	Spacecraft Contract Fee
6.0	ATLO
6.1	Integration and Test Management and Planning
6.2	System Integration and Test
6.3	Launch Operations
6.4	Support Costs
6.5	Spacecraft Integration and Test Support
7.0	Mission Operations
7.1	Ops Management and Infrastructure
7.2	Mission Operations Plan
7.3	Ground Software Development
7.4	Data Processing
7.5	Launch + 30 Days
8.0	Launch Vehicle
9.0	Other
10.0	Reserves
	A. Total Design and Development Cost
Mission Operations and Data Analysis Phase (MO&DA)	
1.0	Project Management
2.0	Science
3.0	Mission Operations
4.0	Other
5.0	Reserves
	B. Total MO&DA Cost
	C. Total Project Cost

H. Preparing a NASA Cost Analysis Requirements Description (CARD)

by Rey Carpio

1. Purpose

This document gives guidance for preparing and updating a Cost Analysis Requirements Description (CARD) document.

2. General Procedures for Preparing and Submitting a CARD

The CARD is to be prepared by the program/project office. The CARD is provided to the estimating teams preparing the program/project office estimate and the Independent Cost Estimate (ICE). A CARD should be regarded as a "living" document that is updated in preparation for program reviews. The updates reflect any changes that have occurred or new data that have become available since the previous program review.

Each CARD should be comprehensive enough to facilitate identification of any area or issue that could have a significant effect on life cycle costs and, therefore, must be addressed in the cost analysis. It also must be flexible enough to accommodate the use of various estimation methodologies. In some sections of the CARD, it may be possible to convey the information pertinent to cost estimation in a few sentences or a single matrix and/or table. In other sections, more detailed information may be required. Note that if a source document is referenced in the CARD, the full document (or pertinent extracts from it) must be included as an attachment to the CARD. NASA Procedures and Guidelines (NPGs) and other widely available references need not be attached. However, the exact location where the widely available information may be found shall be referenced (i.e. title of document, author(s), document number, and physical location).

The level of detail of the information presented in a CARD will vary depending upon the maturity of the program. Understandably, programs at Pre-Phase A, and possibly at Phase A/B, are less well defined than programs at Phase C/D. Accordingly, the CARD for a Phase A program may define ranges of potential outcomes. It is essential that any assumptions made in preparing a CARD for Phase A be identified in the appropriate sections of the document.

The analysts who will be responsible for estimating system costs should review the CARD before it is completed. The purpose of this review is to ensure that the CARD is complete and that it contains all of the information that will be needed to prepare the cost estimates. The cost analysts should not prepare the CARD, however.

3. Contents of a CARD

Every element in the CARD is subject to "tailoring." Cards are divided into a number of sections, each focusing on a particular aspect of the program being assessed. The remainder of this document outlines the basic structure of a CARD and describes the type of information presented in each section.

4. Outline of CARD Basic Structure

-- System Overview

-- System Characterization

This section discusses the basic attributes of the system -- its configuration, the missions it will perform and threats it will counter, its relationship to other systems, and the major factors that will influence its cost. The presentation should be structured as follows:

System Description. This paragraph provides a general description of the system, including the functions it will perform and key performance parameters. The parameters should be those most often used by cost estimators to predict system cost. A diagram or picture of the system, with the major parts and subsystems appropriately labelled, should be included.

System Functional Relationships. This paragraph describes the "top-level" functional and physical relationships among the subsystems within the system as well as the system's relationship to other systems.

System Configuration. This section identifies the equipment (hardware and software).

Work Breakdown Structure (WBS). This section illustrates the WBS for the system.

Government-Furnished Equipment and Property. This paragraph identifies the subsystems that will be furnished by the Government and included in the life cycle cost estimates for the system. Any Government-furnished Commercial Off-The-Shelf (COTS) software should be addressed in the discussion. Where Government-furnished equipment or property is common to other systems, the text should identify how the costs will be accounted for.

-- System Characteristics.
This section provides a technical description of the hardware, software, and human characteristics of the system. It is divided into the following sub-elements:

Technical and Physical Description. This set of paragraphs describe the physical design parameters of the system. A separate discussion is provided for each equipment (hardware and software) WBS item. Physical design parameters should include performance, operational (including system design life), and material (weight and material composition) characteristics. The planned sequence of changes in weight, performance, or operational characteristics that are expected to occur or have historically occurred as the program progresses through the acquisition and operating phases.

These parameters should be reconciled with the system requirements to show that the system is being consistently and realistically defined.

Subsystem Description. This series of paragraphs (repeated for each subsystem) describes the major equipment (hardware/software) WBS components of the system. The discussion should identify which items are off-the-shelf. The technical and risk issues associated with development and production of individual subsystems also must be addressed.

Functional and Performance Description. This subparagraph identifies the function(s) the (..x..) subsystem is to perform. In addition, it describes the associated performance characteristics and lists any firmware to be developed for data processing equipment.

Environmental Conditions. This subparagraph identifies the environmental conditions expected to be encountered during development, production, transportation, storage, and operation of the subsystem. It also identifies any hazardous, toxic, or radiological materials that may be encountered or generated during the subsystem's development, manufacture, transportation, storage, operation, and disposal. The quantities of each hazardous material used or generated over the subsystem's lifetime should be estimated based on the most current operations and maintenance concepts. The discussion should also describe the evaluation methodology for environmentally acceptable alternatives as well as the rationale for selection of alternatives. Finally, the alternatives considered, and reasons for rejection, must be identified.

Material, Processes, and Parts. This subparagraph describes the materials and processes entailed in the development and fabrication of the subsystem. The discussion should identify the respective amount of each material to be used (e.g., aluminum, steel, etc.). In addition, any standard or commercial parts, or parts for which qualified products lists have been established, should be identified.

Workmanship. This subparagraph describes any specific workmanship-related manufacturing or production techniques pertaining to the subsystem.

Commonality. Equipment that is analogous or interchangeable among sub-systems should be identified here. Commonality with subsystems of other systems, or with variants of the basic system, should be identified. Breakouts, by weight, of common and system-specific components should be provided, if applicable.

Software Description. This paragraph describes the software resources associated with the system. It should distinguish among operational, application, and support software and identify which items must be developed and which can be acquired off-the-shelf. The paragraph applies to all systems that use computer and software resources. A software data input form (depending upon the cost model) should be attached to the CARD submission providing more information on the factors that will influence software development and maintenance costs. Use of this data input form is "tailorable" if the same information can be provided in another format, such as a matrix or table. Additionally, this information should be tailored to satisfy specific software model requirements.

Software Sub-elements. This set of paragraphs (repeated for each software sub-element) describes the design and intended uses of system software.

Host Computer Hardware Description. This subparagraph describes the host computer system on which the software sub-element will be operating. This host system should be readily identifiable in the WBS.

Programming Description. This subparagraph identifies programming requirements that will influence the development and cost of the software sub-element. The discussion should address the programming language and programming support environment (including standard tools and modern programming practices) and the compiler(s) and/or assembler(s) to be used.

Design and Coding Constraints. This subparagraph describes the design and coding constraints under which the software will be developed (i.e., protocols, standards, etc.).
Commonality. This subparagraph identifies software that is analogous or interchangeable among sub-elements.

Human Performance Engineering. This paragraph references applicable documents and identifies any special or unique human performance and engineering characteristics (i.e., constraints on allocation of functions to personnel and communication, and personnel and equipment interactions).

System Safety. This paragraph references applicable documents and identifies any special or unique system safety considerations (e.g., "fail safe" design, automatic safety, explosive safety needs, etc.).

System Survivability. This paragraph discusses the survivability capabilities and features of the system. It describes the environments (e.g., nuclear, chemical, biological, fire, etc.) in which the system will be expected to operate, and identifies any unique materials incorporated in the system's design that contribute to its survivability.

-- System Quality Factors

This section identifies key system quality characteristics. System operational availability and the flow down of reliability, availability, and maintainability requirements should be addressed as follows:

Reliability. This paragraph defines system reliability goals in quantitative terms, and defines the conditions under which the goals are to be met.

Maintainability. This paragraph focuses on maintainability characteristics. It describes the planned maintenance and support concept in the following quantitative terms:

- System maintenance man-hours per operating hour, maintenance man-hours per operating hour by major component part of the system, operational ready rate, and frequency of preventative maintenance;
- Maintenance man-hours per overhaul;
- System mean and maximum down time, reaction time, turnaround time, mean and maximum time to repair, and mean time between maintenance actions;
- Number of people required and the associated skill levels at the unit maintenance level;
- Maximum effort required to locate and fix a failure; and
- Specialized support equipment requirements.

Availability. This paragraph defines, in quantitative terms, the availability goals for specific missions of the system. It should identify the percentage of the systems expected to be operable both at the start of a mission and at unspecified (random) points in time.

Portability and Transportability. This paragraph discusses the portability and transportability features of the system (equipment and software) and describes how they affect employment, deployment, and logistic support requirements. Any subsystems whose operational or functional characteristics make them unsuitable for transportation by normal methods should be identified.

Additional Quality Factors. This paragraph describes any quality features not addressed in the preceding paragraphs (i.e., interoperability, integrity, and efficiency features of the system).

-- Embedded Security

If there is embedded security in the system, the software and hardware requirements should be fully identified and described here.

-- Predecessor and/or Reference System

This section describes the predecessor and/or reference system. A predecessor and/or reference system is a currently operational or pre-existing system with a mission similar to that of the proposed system. It is often the system being replaced or augmented by the new acquisition. The discussion should identify key system-level characteristics of both the predecessor and/or reference system and the new or proposed system. Any problems associated with the predecessor system should be discussed, along with any significant differences between the predecessor system and the proposed system. The narrative should also describe how the predecessor system is to be replaced with the proposed system (e.g., one-for-one replacements, etc.). Information on the planned disposition of the replaced systems should be provided so that disposal costs and benefits can be considered in the cost estimate. The above information should also be provided on analogous subsystem and components that can be used to scope or estimate the new system.

-- Risk

This section identifies the program manager's assessment of the program and the measures being taken or planned to reduce those risks. Relevant sources of risk include: design concept, technology development, test requirements, schedule, acquisition strategy, funding, availability, contract stability, or any other aspect that might cause a significant deviation from the planned program. Any related external technology programs (planned or on-going) should be identified, their potential contribution to the program described, and their funding prospects and potential for success assessed. This section should identify these risks for each phase.

-- System Operational Concept

-- Organizational Structure

This section identifies the structure elements associated with the operation of the system. A staffing document should be provided, along with supporting text describing the functions and relationships of the organizational elements. In some cases, staffing documents may not be available for a system until after Phase B. In those instances, notional staffing documents showing the relationship to the staffing documents for the predecessor system should be provided.

-- Security

This paragraph describes the system's physical security, information security, and operations security features. Hardware and software aspects of communications and computer security should also be addressed.

-- Logistics

This paragraph summarizes key elements of the logistics support plan. The information is divided into the following subparagraphs:

Support Concept. These subparagraphs describe the hardware and software support concepts.

Hardware Support Concept. This subparagraph describes the hardware support concept, taking into account: service (organic) versus contractor support requirements, interim support plans, scheduled maintenance intervals and major overhaul points, maintenance levels and repair responsibilities, repair versus replacement criteria, standard support equipment to be used, specialized repair activities, hardness assurance, maintenance, and surveillance plans for systems with critical survivability characteristics and other requirements not previously mentioned.

Software Support Concept. This subparagraph describes the software support concept, including methods planned for upgrades and technology insertions. The discussion should also address post-development software support requirements.

Supply. This paragraph should identify the following: provisioning strategy, location of system stocks, and the methods of resupply, and other effects of the system on the supply system.

<u>Training</u>. This paragraph summarizes the training plans for system operators, maintenance personnel, and support personnel. In the absence of a firm plan, it identifies the following: the training that needs to be accomplished and the organizations that will conduct the training; the number of systems that must be acquired solely for training purposes; the need for auxiliary training devices, the skills to be developed by those devices, and computer simulation requirements; training times and

locations; source materials and other training aids; other training requirements not previously mentioned.

-- Quantity Requirements

This section consists of a matrix identifying the quantities of the system to be developed, tested, produced, and deployed by acquisition phase and year. The quantities identified should be sufficient for maintenance and readiness floats as well as for peacetime attrition requirements. For complete system end-items, the quantities allocated for initial spares and replacement spares should be separately identified.

-- System Staffing Requirements

This section describes the staffing needed to support the system.

-- System Activity Rates

This section defines the activity rates (e.g., number of operating hours per year, flight hours per month or year, operating shifts per day, etc.) for each system or subsystem.

-- System Schedule

This section describes the schedule for the system. Both hardware and software schedules should be discussed. A Gantt chart showing the major milestones of the program by phase (e.g., design reviews, significant test events, reviews) should be provided. A more detailed program master schedule should be included as a reference or appendix. Specific element schedules, if known, should be presented with the descriptions of those elements.

-- Acquisition Plan and/or Strategy

This section describes the acquisition plan for the system. It addresses the following:

-- Contractors

This paragraph identifies the number of prime contractors expected to compete during each phase. The specific contractors and subcontractors involved in each phase should be identified, if known. If this information is source selection sensitive, special labelling of the overall CARD may be required.

-- Contract Type

This paragraph describes the type of contracts to be awarded in each phase of the program. The status of any existing contracts should be discussed.

-- System Development Plan

-- Development Test and Evaluation

This paragraph describes all testing to be accomplished during the program. The number, type, location, and expected duration of tests (for both hardware and software) should be identified, along with the organizations that will conduct the test programs. Examples of tests to include are contractor flight tests, static and fatigue testing, logistic testing to evaluate the achievement of supportability goals, etc. Contractor and Government conducted tests should be separately identified.

-- Operational Test and Evaluation

This paragraph describes all testing to be conducted by agencies other than the developing organization to assess the system's utility, operational effectiveness, operational suitability, logistics supportability, etc. The number, type, location, and expected duration of tests (for both hardware and software) should be identified, along with organizations that will conduct the test programs.

-- Element Facilities Requirements

-- Test and Production Facilities

This paragraph describes the type and number of hardware and software test and production facilities (both contractor and government owed) required during all phases of program.

Separately identify those funded as part of the acquisition prime contract, those separately funded by the program office, and those provided by other activities -- such as a government test organization or facility. Existing facilities that can be modified and/or utilized should be noted. The discussion should describe the size and design characteristics of the respective facilities, along with any land acquisition requirements. The impacts of hazardous, toxic, or radiological materials used or generated during system tests or production should be assessed.

-- Operational Support Facilities

This paragraph describes the type and number of hardware and software facilities required for system deployment, operation and support (including training, personnel, t maintenance, etc.). Existing facilities that can be modified and/or utilized should be noted. The discussion should describe the size and design characteristics of the respective facilities, along with any land acquisition requirements. The impacts of hazardous, toxic, or radiological materials consumed or generated by the system should be assessed.

-- Facilities Commonality

This paragraph identifies the facilities and equipment that are common to this and other programs. The discussion should specify how these items will be accounted for in the cost estimates.

-- Environmental Impact Analysis

This paragraph identifies how environmental impact analysis requirements (including impacts on land, personnel, and facilities) will be accomplished for operational, depot, and training locations, and how the results will be incorporated into the program.

-- Track to Prior CARD

This section summarizes changes from the previous CARD. The discussion should address changes in system design and program schedule, as well as in program direction.

-- Contractor Cost Data Reporting Plan

This section contains a copy of the contractor-government agreement for the contractor to provide cost data to the government. If the agreement has not yet been approved, or is waiting approval, include a copy of the proposed agreement as submitted to Contracts/Procurement office.

For more information on the CARD, please reference the following website:

http://web1.deskbook.osd.mil/htmlfiles/DBY_dod.asp

Within that website, there are several documents that will give further CARD guidance, such as DoD 5000.4-M (also located at http://www.hanscom.af.mil/ESC-BP/pollprev/docs/50004m.pdf, http://www.dtic.mil/whs/directives/corres/html/50004m.htm, and http://web1.deskbook.osd.mil/default.asp (Search for DoD 5000.4-M). This document offers guidance and procedures about the CARD. In particular, Chapter 1 provides useful ideas about the data expectation. Please keep in mind NASA will tailor from the specific structure and content shown for NASA's purposes and to reflect the program as it is. Another useful document is DoD 5000.2-R (also located at http://www.acq.osd.mil/ar/doc/dodd5000-2-r-061001.pdf). Section C4.5.3 of DoD 5000.2-R explains how a CARD is used in the decision making process. Finally, DoD 5000.4 (also located at http://www.dtic.mil/whs/directives/corres/pdf/d50004wch1_112492/d50004p.pdf) addresses the role of the CAIG (Cost Analysis Improvement Group), which is a group of independent cost estimators, in the acquisition management processes within DoD.

CARD SOFTWARE INPUT

CSCI Name ________________________________ **Developer** ________________________________

Operating Environment (Circle One)

Ground   Unmanned Space   Manned Space   Training / Simulation

Development Method (Circle One)

Waterfall   Evolutionary   Spiral (#)_____ Incremental (#)_____

Overall CSCI Application (Circle One)

Database	Command & Control	Communications	OS/Executive	Message Switch
Test	Report Generation	Utilities	Training	Simulation
MIS	Signal Processing	Human/Machine Interface	Graphics	Diagnostics

Complexity / Application	Mix % (This Column Only Must Sum to 100%	% of Row that is New Design	% of Row that is New Code
Operating Systems & Interactive Operations			
Real-Time Cmd & Control			
Online Communications			
Data Storage & Retrieval			
String Manipulation			
Mathematical Operations			
	%		

Size	Least	Likely	Most
New Source Lines			
Reused Source Lines			
% Redesign of Reused			
%Reimplementation of Reused			
%Retest of Reused			

Programming Languages (Name and Percent)

A.___________ %_________   B. _____________ %_________   C. ___________ %_________

Programming Organization Effectiveness and Efficiency

SEI Maturity Level ______   Experience Level (circle one): VH H M L VL
Product Familiarity (circle one): Very Nominal Unfamiliar   New Language? Y or N
SW Tool Kit (circle one): Very Extensive   Extensive   Nominal   Minimal   Bare

CSCI Use/Integration/Security

Number of independent computer programs that will implement the CSCI ________.
Percentage of software that will be responsible for implementing security ________.
Number of other CSCIs that this CSCI will directly integrate with ________.

Software Maintenance

Years of Maintenance ________.   Separate Sites? ________.
Percent of s/w to be maintained: ________%   Maintain total system? Yes___ No____
Maintenance Growth over life _______%.   Annual change rate ________%
Maint Personnel's capabilities/experience in comparison to the development team (circle one)
Higher   Same   Lower
Quality of maintenance environment in comparison to the tools/practices used in development
Higher   Same   Lower
Maintenance Rigor: High (dedicated teams)   Normal   Low (bare bone effort)
Any additional and significant periodic maintenance surge? No___ Yes___
If yes, please describe____
____
____

I. PRICE Systems LLC Overview

PRICE Systems, LLC is the developer and distributor of the PRICE Estimating Suite of parametric modeling tools to be used by engineers, estimators, and project managers for Risk Analysis, Independent Assessment, Contractor Validation, Early Concept Evaluation, Structure and Material Studies, Mission Affordability Studies, What If Analysis, and Total Life Cycle Cost.

PRICE provides training and consulting services that include PRICE For You custom courses, access to the PRICE KnowledgeNetwork, better planning, budgeting and estimating training and mentoring programs, data collection and collaboration process implementation as well as the integration of collaborative PRICE Estimating Suite engineering centers.

About The PRICE Estimating Suite

The PRICE Estimating Suite is a dynamic hardware and software project development solution used to estimate cost and schedules, assist in product planning, and improve project control. The PRICE Estimating Suite consists of the following applications: The PRICE Hardware Estimating Model, PRICE Hardware Life Cycle Estimating Model, PRICE Software Development and Support Cost Model, PRICE Electronic Module, and Microcircuit Estimating Model. As part of the PRICE Estimating Suite, the PRICE KnowledgeNetwork delivers industry benchmark metrics to jumpstart estimates and process improvement, and the PRICE Solution for Microsoft Excel provides a two-way interface that automates what-if analysis, trade-offs, calibration efforts, reports, and proposals.

About the PRICE KnowledgeManager

The PRICE KnowledgeManager is a companion application to the PRICE Estimating Suite that facilitates the process of converting data into knowledge. While supporting qualitative keywords, attributes and structural hierarchy in a collaborative web-enabled environment, the PRICE KnowledgeManager also empowers PRICE Estimating Suite customers to harvest, store, and reuse PRICE hardware project cost elements through the use of powerful trend analysis capabilities.

About PRICE Systems

PRICE Systems is a global leader of integrated planning and estimating solutions that provides software licensing and professional services to Fortune 1000 companies. After 25 years of valuable service and experience to the Aerospace and Defense Industry, PRICE Systems was independently purchased from Lockheed Martin in 1998. Today, PRICE Systems is headquartered in Mt. Laurel, New Jersey with global offices in Dayton, OH, Lexington Park, MD, Los Angeles, CA, Hampshire, UK, Paris, FR, Ruesselsheim, GR and Seoul, KR. Visit PRICE Systems at www.pricesystems.com.

Success with NASA

- NASA has expanded its license to include KnowledgeManager.
- PRICE has added NAFCOM 99 to the KnowledgeBases for KnowledgeManager.
- PRICE has designed custom training courses for NASA and a Jump Start and Turnkey programs to assist analysts with estimates and implementation of the PRICE Estimating Suite.
- PRICE has assisted JPL and MSFC with calibration.
- Anthony DeMarco, President of PRICE Systems, was a member of the International Space Station Management and Cost Evaluation Task Force. "Through our framework of innovative solutions and services, PRICE Systems will provide NASA with the tools and methodologies needed to meet fiscal year success."

Contact Information

PRICE Systems, LLC
17000 Commerce Parkway, Suite A
Mt. Laurel, NJ 08033
Tel: 1-800-43-PRICE
Fax: 856-608-7247
http://www.pricesystems.com/

PRICE H INPUT SHEET

1. NAME OF UNIT	2. NAME OF CONTRACTOR	3. WORK BREAKDOWN STRUCTURE ELEMENT NO.

4a. CONTRACT LINE ITEM NO.	5. QTY OF THIS UNIT USED IN AND NAME OF NEXT HIGHER ASSY
4b. REFERENCE TECH VOL.	6. NAME OF SYSTEM OR SUBSYSTEM

7a. SOURCE OF UNIT	7b. IF MANUFACTURED, ENTER % NEW DESIGN REQUIRED & % DESIGN REPEAT			
☐ NEW DEVELOPMENT	PERCENT OF TOTAL STRUC/MECHANICAL		PERCENT OF TOTAL ELECTRONIC	
☐ PURCHASED (SEE NO. 8)	% New Design		% New Design	
☐ *- OFF THE SHELF*	% Des Repeat		% Des Repeat	
☐ *-CUSTOM MADE*	7c. IF PURCHASED OR GFE, ENTER % MODIFICATION REQUIRED			
☐ GFE	PERCENT OF TOTAL STRUC/MECHANICAL		PERCENT OF TOTAL ELECTRONIC	

8. IF PURCHASED	PROTOS UNIT COST $	PROD. UNIT COST $	☐ FIXED ☐ TO BE ESCALATED	YEAR $
9. WEIGHT AND VOLUME	TOTAL UNIT WEIGHT (LBS)	STRUCTURE WEIGHT	UNIT DIM OR VOL	

10. STRUCTURAL INTEGRATION & TEST DESCRIPTION

☐ **Simple interface** Integration: Simple boltdown, flange or mounting feet utilized; up to 6 fasteners; minimal tools Test: Inspection, but no actual testing required	☐ **New, but familiar & routine interface** Integration: Medium precision alignment/fit between items; some special tools used; multiple surfaces; some adjustment of surfaces Test: Performance meets specifications
☐ **Routine interface** Integration: Alignment and bolt-down; up to 12 fasteners; standard tools Test: Clearances and dimensions; observe any mechanical ad	☐ **Moderately difficult interface** Integration: Requires medium precision alignment; requires specials tools and/or fixtures Test: Includes dimension and performance measurement; needs some special gauges and custom tests
	☐ **Difficult interface** Integration: Requires precision alignment using special jigs & tools, possibly monolithic; matching and/or timing adjustment Test: Requires full specification testing; requires set of test gauges and special test facilities

11. ELECTRONIC INTEGRATION & TEST DESCRIPTION

☐ **Simple Interface** Integration: Plug-in electronic connection Test: If testing is required, then auto-test; no calibration	☐ **Moderately difficult interface** Integration: Several plug-in connections; number of wire connections Test: Requires adjustment and calibration of several items
☐ **Routine Interface** Integration: Plug-in connections; possible wire connections Test: Some auto/semi-auto tests; some adjustments	☐ **Difficult interface** Integration: Multiple connectors/connections Test: Significant testing with adjustment and calibration required; probable interaction with other items, Vendor, or CFE integration
☐ **New, but familiar & routine interface** Integration: Plug-in electronic connection; some wire conne Test: Semi-auto tests, adjustments, possible simple calibrations.	☐ **Advanced State-of-the-Art interface** Integration: Many connectors/connections Test: Heavy auto and manual testing; full calibration and adjustments with many other Vendor or CFE items; lengthy time and documentation requirements.

12. ENGINEERING COMPLEXITY

12a. SCOPE OF ENGINEERING DESIGN EFFORT

☐ **Simple mods:** Simple modifications to an existing design	☐ **New product:** New design different from established product line. Uses existing materials and/or electronic components.	☐ **Advance SOTA:** State of the Art being advanced or multiple design paths required to reach goal.
☐ **Extensive mods:** Extensive modifications to an existing design	☐ **New technology:** New design that is different from established product line. Requires in-house development or new electronic components or new materials and processes.	
☐ **New design:** New design within established product line; continuation of existing state of the art.		

12b. EXPERIENCE OF ENGINEERING DESIGN TEAM

☐ **Very experienced:** Extensive experience with similar type designs. Many experts in field. Top talent leading effort.	☐ **Average:** Normal experience. Engineers have completed similar type designs	☐ **Inexperienced.** Engineers are unfamiliar with the design. Many are new to the job.
	☐ **Mixed Experience:** Some are familiar with this type design, others are new to the job.	

13. HARDWARE/SOFTWARE INTEGRATION COMPLEXITY

13a. SCOPE OF SOFTWARE/HARDWARE INTEGRATION EFFORT

☐ **Existing + New (Simple)** Existing HW with new SW or new HW with existing SW. Simple interfaces, normal timing.	☐ **Mod + New (Complex):** Modified HW with new SW or new HW with modified SW. Complex interfaces and critical timing.	☐ **Purchased/Furnished:** HW or SW is purchased or furnished. Timing and communications problems are anticipated.
☐ **Mod + New (Normal):** Modified HW with new SW or new HW with modified SW. Normal interfaces and timing.	☐ **New + New.** New HW and new SW design. New interfaces with normal timing and transfer rates.	

13b. EXPERIENCE OF SOFTWARE/HARDWARE INTEGRATION TEAM

☐ **Very experienced.** Personnel with extensive experience in integration. Some top talent. Control/Change Procedures (C/CPs) are in place	☐ **Average.** Normal Crew, some experience. C/CPs are in place	☐ **Inexperienced.** Crew is inexperienced. Many new hires. No procedures.
	☐ **Mixed Crew.** Some experience in integration. Some new hires. C/CPs are inadequate	

14. UNIT QUANTITY AND SCHEDULES

PROGRAM PHASE	QUANTITIES		SCHEDULE		
	IN ENGINEERING SHOP (Include non-deliverables)	IN PRODUCTION FACILITY (Include non-deliverables)	PHASE START DATE	FIRST UNIT COMPLETE DATE	LAST UNIT COMPLETE DATE
DEVELOPMENT					
PRODUCTION					

15a. DESCRIBE PRODUCTION PROCESS (Automated-Skilled Labor, Etc.)	15b. DEGREE OF AUTOMATION	MECHANICAL	ELECTRONICS	15c. INDICATE LEARNING CURVE- INDUSTRIAL (Material, Labor and Type of L/C)
MECHANICAL	MAXIMUM	☐	☐	
	NORMAL	☐	☐	
ELECTRONICS	MINIMUM	☐	☐	

16. REMARKS (Use additional pages as necessary)	17. NAME AND PHONE NUMBER OF PREPARER

CONCEPTUAL COMPLEXITY GENERATOR

1. NAME OF UNIT	**2. NAME OF CONTRACT**
3. WORK BREAKDOWN STRUCTURE ELEMENT NO.	
4a. CONTRACT LINE ITEM NO.	**5. QTY OF THIS UNIT USED IN AND NAME OF NEXT HIGHER ASSY**
4b. REFERENCE TECH VOL.	**6. NAME OF SYSTEM OR SUBSYSTEM**

MCPLXS - CONCEPTUAL COMPLEXITY GENERATOR FOR STRUCTURAL ITEM

7. CONSTRUCTION AND FUNCTION

☐ Sheet Metal	☐ Machined	☐ Laminated construction
☐ Support, no moving parts	☐ Machined parts for support/containment	☐ Laid up flat surface with stiffness
☐ Containment under static forces	☐ Precision machined parts in assembly	☐ Structural frames, supports, bulkheads
☐ Bears significant dynamic forces	☐ High precision optical components	☐ Cylindrical shaped, filament wound

8. PRIMARY MATERIAL	**9. PLATFORM**	
☐ Aluminum alloys, bronze	☐ Manned Space	☐ Mobile Ground - Military
☐ Steel alloys, yellow brass	☐ Unmanned Space	☐ Mobile Ground - Missiles (Grd-Air, Grd-Grd)
☐ Tungsten, copper alloys	☐ Airborne Missiles (Air-Air, Air-Grd)	☐ Ground - Military
☐ Titanium, Ni-based alloys	☐ Airborne Military	☐ Ground - Commercial
☐ Matrix composites, glass, ceramics	☐ Airborne Commercial	☐ Other

10. NUMBER OF STRUC PARTS	**11. MACHINABILITY, Enter material to be machined (e.g., Al 2024)**

MCPLXE - CONCEPTUAL COMPLEXITY GENERATOR FOR ELECTRONIC ITEM

12. ELECTRONIC DESCRIPTION BY PERCENTAGE OF CONTENT

TYPE	%DISC	%SSIC	%MSIC	%LSI	%VLSI	VHSIC GA	VHSIC MEM
ANALOG AUDIO							
ANALOG RF/VIDEO							
DIGITAL							
DISPLAY							
DISPLAY NO CRT							
TRANSMITTER							
POWER SUPPLY/VLSI MEM							

13. QUALITY ADJUSTMENT

	Parts Qual	Description/Examples
☐	S	QPL spacecraft and other very long life projects
☐	S1	Very, very high rel proj; e.g., manned spacecraft
☐	B	Very high rel parts; used in inaccessible places
☐	B1	High qual parts; e.g., civil aircraft; safety eqmt
☐	B2	Rel chosen to reduce maint costs of long-life eqmt
☐	D	Brand names, quality components
☐	D1	Commercial grade; some infant mortality allowed
☐	Other	

14. NAME AND PHONE NUMBER OR PREPARER

15. REMARKS

(Adjustments to inputs, computation of MCPLXS/E calibration factors, comparisons to PRICE or NAFCOM calibrated table values, etc.)

Kelley Cyr and Richard Whitlock at JSC modified these PRICE Input Sheets.

J. Galorath Incorporated Overview

Galorath Incorporated is the developer and distributor of the SEER™ suite of advanced modeling tools helping engineers, managers, and cost analysts plan and control critical projects. Galorath offers six tools in its suite:

1. **SEER-SEM™** (Software Estimation Model)
2. **SEER-SSM™** (Software Sizing Model)
3. **The SEER-SEM™ Client for Microsoft Project** (Direct integration with Microsoft Project)

These models are used to build realistic schedule, project cost and staffing estimates; Evaluate quality and reliability potential; Gauge maintenance, upgrade and life-cycle costs; Compare costs and benefits of reuse, off-the-shelf software, or modern development methods.

SEER-SEM Sizing Inputs

WBS Description: ______________________ ☐ Program ☐ Component ☐ Unit

Selected Knowledge Bases			
Platform		Development Method	
Application		Development Standard	
Acquisition Method		Class	

Parameter	Least	Likely	Most	Rationale
+ LINES				
- New Lines of Code				
+ Pre-exists, not designed for reuse				
- Pre-existing lines of code				
- Lines to be deleted in pre-exstg				
- Redesign required				
- Reimplementation required				
- Retest required				
+ FUNCTIONS				
+ NEW				
- New Functions				
- Software phase at estimate				
+ Pre-exists, not designed for reuse				
- Pre-existing functions				
- Funcs to be deleted in pre-exstg				
- Software phase at estimate				
- Redesign required				
- Reimplementation required				
- Retest required				

4. **SEER-H™** (Hardware estimation & life-cycle cost analysis)
5. **SEER-IC™** (Custom Integrated Circuit Development)

These tools can be applied to all hardware products from simple structures and mechanical devices to hydraulics, electronics, and even complex aerospace or integrated circuit programs. They are used to resolve make-versus-buy decisions; Gauge operations support and life-cycle costs; Analyze complex and interdependent design and production trade-offs.

6. **SEER-DFM**™ (Design for Manufacturability) with Composites Plug-in
This tool allows you to evaluate any part, process or assembly alternative; Analyze manufacturing trade-offs; Build realistic labor, materials and tooling estimates. You can make smart decisions about trade-offs and alternative approaches before manufacturing begins, because you can choose the most efficient production and assembly methods.

SEER-H Inputs Electronics Work Elements

WBS Description: ______________________

Selected Knowledge Bases			
Application		Acquisition Category	
Platform		Development Standard	
O&S Description		Class	

Parameter	Least	Likely	Most	Rationale
+ PRODUCT DESCRIPTION				
- Total Printed Circuit Boards				
+ CIRCUITRY COMPOSITION				
- Percent Analog				
- Percent Digital				
- Percent Hybrid				
- Discrete Components Per PCB				
- Surface Mount Discretes				
- Integrated Circuits Per PCB				
- Surface Mount ICs				
- Input/Output Pins Per PCB				
- Clock Speed (MHz)				
- Packaging Density				
- IC Technology				
- Custom Chip Usage				

SEER-H Inputs Mechanical/Structural Work Elements

WBS Description: ______________________

Selected Knowledge Bases			
Application		Acquisition Category	
Platform		Development Standard	
O&S Description		Class	

Parameter	Least	Likely	Most	Rationale
+ PRODUCT DESCRIPTION				
- Weight (lb|kg)				
- Volume (cubic feet|meters)				
+ MATERIAL COMPOSITION				
- Percent Aluminum/Malleable Metal				
- Percent Steel Alloy				
- Percent Commrcl Available Exotic				
- Percent Other Exotic				
- Percent Composite				
- Percent Polymer				
- Percent Ceramic				
- Complexity of Form				
- Complexity of Fit				
- Construction Process				

Success with NASA

"SEER provides a time-efficient and accurate method for generating cost estimates."
-Mahmoud Naderi, Marshall Space Flight Center, 2001

Contact Information

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K. COTS, GOTS, & Center Unique Tools & Methods

List of Models (including characteristics and descriptions)

Model Name (Title)	Source			Model Characteristics																	Description
	Commercial	Government	Other	Beta Curve	Cost Estimating	CER	Database	Evaluation	Inflation	Handbook	Hardware Estimating	Learning Curve	O&S	Parametric	Proposal	Risk	Schedule	Spreadsheet	Software Estimating	Software Program	
Advance Missions Cost Model (AMCM)		x			x						x										Provides ROM estimates for the development and production of spacecraft, space transportation systems, aircraft, missiles, ships and land vehicles.
Aircraft Turbine Engine Cost Model (ATECM)		x			x						x										Estimates the development and production costs and time of arrival of aircraft turbine engines.
Airframe Cost Model		x																			Estimates the development and production costs of aircraft airframes that is suitable for use in a program's conceptual stage when little detailed information is available.
AATe – Architectural Assessment Tool – enhanced		x					x														Combination database and knowledge base. A conceptual design phase tool best used in comparing multiple concepts with level assumptions.
Army Military-Civilian Cost System (AMCOS)		x			x																AMCOS is a user-friendly, PC-based tool used to support military and civilian cost estimation.
Automated Cost Estimating Integrated Tools (ACEIT)	x			x	x				x			x							x		ACEIT helps analysts store, retrieve, and analyze data; build cost models; analyze risk; time phase budgets; and document cost estimates.
Best Estimate	x				x															x	Estimator for renovators and remodelors general contractors, design/builders, architects and designers.
C Risk (A Cost Risk Analysis Tool)			x													x				x	Analytic (rather than a Monte Carlo simulation) risk analysis package. Requires minimal inputs compared to other risk models (best estimate, standard error of estimate, % of new technology).
Cobra	x																				System for managing project costs, measuring earned value, and analyzing budgets, actuals, and forecasts.
COCOPRO			x		x														x	x	Implements Boehm's COCOMO technique for estimating costs of software projects. It supports the intermediate COCOMO model, and allows automatic calibration of the model to a cost history database.
CODECOUNT(TM)			x																x	x	This CodeCount toolset is a collection of tools designed to automate the collection of source code sizing information. The CodeCount toolset spans multiple programming languages and uses one of two possible Source Lines of Code (SLOC) definitions, physical or logical.
Constructive Cost Model (COCOMO) II			x		x								x				x		x	x	An open box software cost estimating tool created by Barry Boehm and his staff. This program is an implementation of the 1981 COCOMO Intermediate Model. It predicts software development effort, schedule, and effort distribution. It is available for SunOS or MS Windows and can be downloaded for free.
Consumer Price Index (CPI) Inflation Calculator		x							x												Calculator for adjusting cost of living from one year to another using the Consumer Price Index (CPI) inflation index.
COOLSoft	x				x								x						x	x	Uses a hybrid of intermediate and detailed versions of COCOMO. This allows for the reuse of existing code, development of new code, the purchase and integration of third party code, and hardware integration.
COSMIC			x				x														Over 810 computer programs that were originally developed by NASA and its contractors for the U.S. space program.
Cost Analysis Strategy Assessment (CASA) Model		x			x								x								Life Cycle Cost (LCC)/Total Ownership Cost (TOC) decision support tool. CASA can present the total cost of ownership depending on user selections: including RDT&E costs, production costs, and operating/support costs. CASA covers the entire life of the system, from its initial research costs to those associated with yearly maintenance, as well as spares, training costs, and other expenses.
Cost Estimating Cost Model		x			x						x										Estimates the cost of doing estimates for Deep Space Network (DSN) projects.
Cost of Manpower Estimating Tool (COMET) v2.0		x			x	x	x						x							x	A software database and cost estimating tool which provide users with the O&S estimates for the cost of Navy manpower.
Cost Spreading Model		x		x																	This is a simple online cost spreading calculator that can be used to spread the estimated cost of a program up to 8 years.

List of Models (including characteristics and descriptions) *continued*

Model Name (Title)	Source			Model Characteristics																				Description
	Commercial	Government	Other	Beta Curve	Cost Estimating	CER	Database	Evaluation	Inflation	Handbook	Hardware Estimating	Learning Curve	O&S	Parametric	Proposal	Risk	Schedule	Spreadsheet	Software Estimating	Software Program	
CostTrack	x																x				Integrated cost/project management software package.
Cost Xpert	x				x								x				x		x	x	Software costing tool calculates information including project costs, schedules, tasks, deliverables, maintenance, and support requirements.
Costar			x		x												x		x	x	To produce estimates of a project's duration, staffing levels, effort, and cost.
COSTIMATOR	x				x																Computerized cost estimating and process planning for manufacturing.
Crystal Ball	x															x				x	Choose a range for each uncertain value in your spreadsheet. Crystal Ball uses this information to perform hundreds of what-if analyses. These analyses are summarized in a graph showing the probability for each result.
DeccaPro	x				x										x					x	Activity based cost estimating software.
Decision by Life Cycle Cost	x							x												x	A software package for automated life cycle cost evaluation and cost effectiveness analysis.
DecisionTools Suite (@RISK, BestFit, TopRank, and Riskview)	x															x		x		x	Provides a suite of integrated decision analysis programs running from a common toolbar in Microsoft Excel. (@RISK, PrecisionTree, TopRank, BestFit, and RISKview)
Department of Defense (DoD) Tools and Models Index	x	x		x	x	x	x				x	x	x	x		x	x	x	x	x	Index contains abstracts of tools and models that are currently used in the DoD and have the potential for wider application.
Employment Cost Index (ECI) Inflation Calculator		x							x												Calculator for adjusting costs from one year to another using the Employment Cost Index (ECI) inflation index.
Environmental Costs of Hazardous Operations (ECHO) Model		x			x															x	The model calculates the environmental cost incurred throughout a life cycle cost of a program.
European Space Agency (ESA) Cost Modeling Software (ECOM)		x			x														x	x	ECOM is a Software tool for collection, retrieval and processing of cost data from past ESA programmers and projects.
European Space Agency (ESA) Costing Software (ECOS)		x			x														x	x	European Space Agency (ESA) Costing Software.
FRISK (Formal Risk Assessment of System Cost Estimates)			x													x				x	Analytic (rather than a Monte Carlo simulation) risk analysis package. Inputs are assumed to have a triangular distribution while the total system cost is approximated by the lognormal distribution.
GDP Deflator Inflation Calculator		x							x												Calculator for adjusting costs from one year to another using the Gross Domestic Product (GDP) inflation index.
International Price Index (IPI) Inflation Calculator		x							x												Calculator for adjusting costs from one year to another using the International Price Index (IPI) inflation index.
Labor & Materials		x			x													x			This document contains instructions for preparing labor and materials cost estimates. This type of cost estimating is also referred to as grass-roots or bottoms-up estimating.
Learning Curve Calculator		x										x									Uses the learning curve to estimate the unit, average, and total effort required to produce a given number of units.
Mission Operations Cost Model		x			x																Simple online mission operations cost model (MOCM) that provides a useful method for quick turnaround, rough-order-of-magnitude cost estimating.
NAFCOM96 Cost Model (Government & Unrestricted)		x			x	x	x			x	x		x							x	An innovative computer model for estimating aerospace program costs.
Navy Obligation Data Extraction System (NODES)		x					x														NODES is an unclassified database of historical Navy operating and support obligations. It contains Navy operations and maintenance (OMN) and military personnel (MPN) cost detail for 1995 through 2000. NODES obtains data from budget and account sources and is updated annually.

List of Models (including characteristics and descriptions) *continued*

Model Name (Title)	Source			Model Characteristics																	Description
	Commercial	Government	Other	Beta Curve	Cost Estimating	CER	Database	Evaluation	Inflation	Handbook	Hardware Estimating	Learning Curve	O&S	Parametric	Proposal	Risk	Schedule	Spreadsheet	Software Estimating	Software Program	
Operating and Support Cost Analysis Model (OSCAM)		x											x								OSCAM provides a means of analyzing operating and support (O&S) costs of various military systems. The objective of the OSCAM Program is to provide a tool for assessing the impact of alternative maintenance strategies and operating policies on cost and availability for these systems.
Parametric Construction Cost Estimating System (PACES)	x				x									x							Integrated PC-based budgeting and cost estimating system that prepares parametric cost estimates for new facility construction, renovation, and life cycle cost.
PRICE-H/HL/M (Parametric Review of Information for Cost & Evaluation of Hardware and Electronics)	x				x						x		x	x						x	Estimates cost and schedule for total life cycle of hardware systems - from systems concept phase through maintenance and support. PRICE H is the hardware estimating model, PRICE HL is the hardware life cycle estimating model, and PRICE M is the electronic module and microcircuit estimating model.
PRICE-S (Parametric Review of Information for Cost & Evaluation of Software)	x				x								x	x					x	x	Estimates cost and schedule for total life cycle of software systems - from systems concept phase through maintenance and support.
Primavera Suite	x														x	x	x			x	An integrated way to manage people, teams, and projects using products such as: Primavera Project Planner, Expedition Express.
Producer Price Index (PPI) Inflation Calculator		x							x												Calculator for adjusting costs from one year to another using the Producer Price Index (PPI) inflation index.
Resource Data Storage and Retrieval System (REDSTAR)		x					x														NASA-wide repository of cost programmatic, and technical data pertaining to space related projects and programs.
Revised Intermediate COCOMO (REVIC)		x			x								x						x	x	Estimates software development and maintenance costs: development costs from requirements analysis through completion of acceptance testing and software maintenance costs for 15 years.
SEER-DFM	x							x						x						x	Shows how specific design and process decisions will affect production cost.
SEER-H (System Evaluation & Estimation of Resources - Hardware Estimation Model)	x				x						x		x	x			x			x	Estimates hardware costs, schedule, and risk for the requirements, design, test, integration and test, and maintenance phases.
SEER-IC	x				x						x			x						x	Estimates custom integrated circuit development and production costs, generates specifications, and evaluates potential yields.
SEER-SEM (System Evaluation & Estimation of Resources - Software Estimation Model)	x				x								x	x		x	x		x	x	Estimates software costs, schedule, and risk for the requirements, design, test, integration and test, and maintenance phases.
SEER-SM	x													x					x	x	A software sizing tool that creates estimates of a project's scope.
SEER-SSM (System Evaluation & Estimation of Resources - Software Sizing Model)	x												x	x					x	x	Estimates the expected size of a software project (in lines of code) with minimal input.
Small Satellite Cost Model (SSCM)			x		x						x									x	Estimates the development and production costs of a small satellite bus for Earth-orbiting or near-planetary spacecraft.
Space Operations Cost Model (SOCM)		x			x													x			The model estimates post-launch Mission Operations & Data Analysis (MO&DA) staffing and cost requirements and includes cost relationships for several Space Operations Management Office (SOMO) services (tracking network costs and others).
Spacecraft/Vehicle Level		x			x																Provides ROM estimates for the development and production of spacecraft, launch vehicle stages, engines and scientific instruments.
SPSS Tools Suite	x																				Toolkit of statistics, graphs, and reports for use in a variety of applications in commercial, academic, and Government settings. Applications include surveys, marketing and sales analysis, data mining, quality improvement, and statistical research of all types.
Visibility and Management of Operating and Support Costs (VAMOSC)		x					x														The Navy VAMOSC management information system collects and reports U.S. Navy and U.S. Marine Corps historical weapon system operating and support (O&S) costs.
Unmanned Space Vehicle Cost Model 8th Edition		x			x	x	x			x	x							x			Contains Cost Estimating Relationships (CERs) for estimating subsystem and component cost of a space vehicle.

List of Models (including POCs, telephone numbers, and web addresses)

Model Name (Title)	Author/Company/Organization	Contact Information	
		Office Number	Web Address
Advance Missions Cost Model (AMCM)	NASA		http://www.jsc.nasa.gov/bu2/AMCM.html
Aircraft Turbine Engine Cost Model (ATECM)	NASA		http://www.jsc.nasa.gov/bu2/ATECM.html
Airframe Cost Model	NASA		http://www.jsc.nasa.gov/bu2/airframe.html
AATe – Architectural Assessment Tool – enhanced	NASA (Edgar Zapata)	(321) 867-6234	http://science.ksc.nasa.gov/shuttle/nexgen/AATe_Info.htm
Army Military-Civilian Cost System (AMCOS)	Army		http://www.ceac.army.mil/amcos/amcosweb/demo/frame.htm
Automated Cost Estimating Integrated Tools (ACEIT)	Tecolote	(805) 964-6963	http://www.aceit.com/
Best Estimate			http://www.ConstructionTradeShow.com/ http://www.best-estimate.com/
C Risk (A Cost Risk Analysis Tool)	Aerospace Corporation (P.L. Smith and S.A. Book)	(310) 336-5000	http://web1.deskbook.osd.mil/valhtml/2/2B/2B4/2B4S09.htm
Cobra	Welcom		http://www.welcom.com/content.cfm?node=10
COCOPRO	Dr. Barry Boehm	(213) 740-8163	http://www.iconixsw.com/Spec_Sheets/CoCoPro.html
CODECOUNT(TM)	Dr. Barry Boehm	(213) 740-8163	http://sunset.usc.edu/available_tools/index.html
Constructive Cost Model (COCOMO) II	Dr. Barry Boehm	(213) 740-8163	http://sunset.usc.edu/available_tools/index.html
Consumer Price Index (CPI) Inflation Calculator	NASA		http://www.jsc.nasa.gov/bu2/inflateCPI.html
COOLSoft	Wright Williams & Kelly	(925) 485-5711	http://www.wwk.com/coolsoft.html
COSMIC	Open Channel Foundation / NASA		http://www.openchannelfoundation.org/cosmic/
Cost Analysis Strategy Assessment (CASA) Model	USAMC Logistics Support Activity		http://www.logsa.army.mil/alc/casa/
Cost Estimating Cost Model	NASA		http://www.jsc.nasa.gov/bu2/CECM.html
Cost of Manpower Estimating Tool (COMET) v2.0	Naval Center for Cost Analysis (NCCA)		http://www.ncca.navy.mil/services/comet/index-frame.htm
Cost Spreading Model	NASA		http://www.jsc.nasa.gov/bu2/beta.html
CostTrack	Ontrack Engineering Ltd.	(403) 251-5678	http://www.ontrackengineering.com/Software.html
Cost Xpert	Cost Xpert Group, Inc.	(619) 670-6168	http://www.costxpert.com/
Costar	Dr. Barry Boehm	(213) 740-8163	http://www.softstarsystems.com/
COSTIMATOR	MTI Systems, Inc.	(800) 644-4318	http://www.costimator.com/
Crystal Ball	Decisioneering	(800) 289-2550	http://www.decisioneering.com/crystal_ball/index.html
DeccaPro	Deccan System Inc.	(812) 948-8726	http://www.deccansystems.com/DeccaPro.htm
Decision by Life Cycle Cost	Advanced Logistics Developments (ALD)	(800) 292-4519	http://www.ald.co.il/products/dlcc.html
DecisionTools Suite (@RISK, BestFit, TopRank, and Riskview)	Palisade	(800) 432-7475	http://www.palisade.com/html/decision_analysis_software.html
Department of Defense (DoD) Tools and Models Index			http://www.c3i.osd.mil/bpr/dodim/costool.html
Employment Cost Index (ECI) Inflation Calculator	NASA		http://www.jsc.nasa.gov/bu2/inflation/eci/inflateECI.html
Environmental Costs of Hazardous Operations (ECHO) Model	Naval Air Systems Command/Tecolote	(805) 964-6963	http://www.tecolote.com/Services/Models.htm
European Space Agency (ESA) Cost Modeling Software (ECOM)	Advantage Software B.V.	+31 20 6148649	http://www.estec.esa.nl:80/eawww/ecom/ecom.htm
European Space Agency (ESA) Costing Software (ECOS)	Advantage Software B.V.	+31 20 6148649	http://www.estec.esa.nl:80/eawww/ecos/ecos.htm
FRISK (Formal Risk Assessment of System Cost Estimates)	Aerospace Corporation (Phillip H. Young)	(310) 336-5000	http://web2.deskbook.osd.mil/valhtml/2/2B/2B4/2B4S06.HTM
GDP Deflator Inflation Calculator	NASA		http://www.jsc.nasa.gov/bu2/inflateGDP.html
International Price Index (IPI) Inflation Calculator	NASA		http://www.jsc.nasa.gov/bu2/inflation/ipi/inflateIPI.html
Labor & Materials	NASA		http://www.jsc.nasa.gov/bu2/instruct.html
Learning Curve Calculator	NASA		http://www.jsc.nasa.gov/bu2/learn.html
Mission Operations Cost Model	NASA		http://www.jsc.nasa.gov/bu2/MOCM.html
NAFCOM96 Cost Model (Government & Unrestricted)	NASA/Air Force/SAIC (Keith Smith)	(256) 971-6571	http://www.jsc.nasa.gov/bu2/NAFCOM.html
Navy Obligation Data Extraction System (NODES)	NCCA		http://www.ncca.navy.mil/services/nodes.cfm
Operating and Support Cost Analysis Model (OSCAM)	NCCA and United Kingdom's Ministry of Defense (UK MoD)		http://www.oscamtools.com/
Parametric Construction Cost Estimating System (PACES)	Talisman Partners Ltd	(303) 771-3103	http://www.talpart.com/products/paces/
PRICE-H/HL/M (Parametric Review of Information for Cost & Evaluation of Hardware and Electronics)	PRICE Systems	(800) 43-PRICE	http://www.pricesystems.com/
PRICE-S (Parametric Review of Information for Cost & Evaluation of Software)	PRICE Systems	(800) 43-PRICE	http://www.pricesystems.com/
Primavera Suite	Primavera	(800) 423-0245	http://www.primavera.com/
Producer Price Index (PPI) Inflation Calculator	NASA		http://www.jsc.nasa.gov/bu2/inflation/ppi/inflatePPI.html
Resource Data Storage and Retrieval System (REDSTAR)	NASA/SAIC		http://redstar.saic.com/
Revised Intermediate COCOMO (REVIC)	Raymond Kile	(703) 604-0395	http://sepo.nosc.mil/sepo/estimation.html
SEER-DFM	Galorath Inc.	(310) 414-3222	http://www.galorath.com/home.shtm
SEER-H (System Evaluation & Estimation of Resources - Hardware Estimation Model)	Galorath Inc.	(310) 414-3222	http://www.galorath.com/home.shtm
SEER-IC	Galorath Inc.	(310) 414-3222	http://www.galorath.com/home.shtm
SEER-SEM (System Evaluation & Estimation of Resources - Software Estimation Model)	Galorath Inc.	(310) 414-3222	http://www.galorath.com/home.shtm
SEER-SM	Galorath Inc.	(310) 414-3222	http://www.galorath.com/home.shtm
SEER-SSM (System Evaluation & Estimation of Resources - Software Sizing Model)	Galorath Inc.	(310) 414-3222	http://www.galorath.com/home.shtm
Small Satellite Cost Model (SSCM)	Aerospace Corporation (Jim Summers)	(310) 336-6802	http://www.aero.org/software/sscm/
Space Operations Cost Model (SOCM)	NASA		http://www.jsc.nasa.gov/bu2/SOCM/SOCM.html
Spacecraft/Vehicle Level	NASA		http://www.jsc.nasa.gov/bu2/SVLCM.html
SPSS Tools Suite	SPSS Inc.	(312) 651-3000	http://www.spss.com/products/
Visibility and Management of Operating and Support Costs (VAMOSC)	NCCA		http://www.navyvamosc.com/
Unmanned Space Vehicle Cost Model 8th Edition	Air Force (Phu Nguyen)	(310) 363-0071	

L. NASA Jump Start Program

JUMP START Program

"Where do I start?"

To provide a running start on estimating at any Center by any new/experienced analyst (not just estimators), JUMP START will answer the common predicament faced by a new estimator challenged with a new project. Because of this situation, the estimator may end up asking a familiar question, "Where do I start?" Offering an immediate solution to these recurring situations, IPAO has provided the contractual vehicle for parametric model users to help setup the minimum required project-estimating task, allowing one to two days effort of expert help. The end results, in a relatively short time, are the new estimators--walking alone doing their own estimates.

The use of PRICE or SEER products requires the NASA user to setup the PRICE or SEER files by work breakdown structures and meaningful configuration of the estimating task. To facilitate this initial effort, each user requires a minimum effort that must be augmented by PRICE and SEER consultants to establish the first few steps of creating PRICE or SEER files. PRICE or SEER consultants will "Jump Start" the estimating and programmatic tasks.

Objective: The objective of JUMP START is to provide minimum technical assistance to NASA cost analysts throughout the Agency in conducting cost estimates and other programmatic tasks using PRICE or SEER products. This is a level of effort (labor-hours only) deliverable. Furthermore, each sub-task cannot be more than $3K each or 24 hours of expert consultation.

Task: The contractor will provide support to the NASA PRICE or SEER Model analyst in creating the cost estimate. The support will be in the form of mentoring the NASA PRICE or SEER Model analyst in creating model data files, data collection and evaluation, and model output evaluation.

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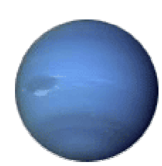
M. NASA New Start Inflation Indices

The "new start" inflation index should be appropriately used. It is intended to estimate escalation when contractor forward pricing rates are not known. It should not be used if better (contractual) information is available. This index should be used for new R&D developments only and does not apply to either operations or support service contractor costs.

The new start inflation index starts in 1959, but for illustration purposes, the screen shot below only shows the new start inflation indices from 1998 through 2010. To get the full index please contact Chris Chromik from the IPAO. He can be reached at 757-864-7208 or c.c.chromik@larc.nasa.gov. This index was updated as of February 8, 2002.

2/8/2002 YEAR	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Note:
INFL.RATE	1.1%	2.0%	3.3%	3.1%	2.6%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	3.1%	Use 3.1% for out years
FACTORS	1.011	1.020	1.033	1.031	1.026	1.031	1.031	1.031	1.031	1.031	1.031	1.031	1.031	FROM
FROM 1998	1.000	1.020	1.054	1.087	1.115	1.149	1.185	1.222	1.260	1.299	1.339	1.380	1.423	1998
FROM 1999		1.000	1.033	1.065	1.093	1.127	1.162	1.198	1.235	1.273	1.312	1.353	1.395	1999
FROM 2000			1.000	1.031	1.058	1.091	1.124	1.159	1.195	1.232	1.270	1.310	1.350	2000
FROM 2001				1.000	1.026	1.058	1.091	1.124	1.159	1.195	1.232	1.270	1.310	2001
FROM 2002					1.000	1.031	1.063	1.096	1.130	1.165	1.201	1.238	1.277	2002
FROM 2003						1.000	1.031	1.063	1.096	1.130	1.165	1.201	1.238	2003
FROM 2004							1.000	1.031	1.063	1.096	1.130	1.165	1.201	2004
FROM 2005								1.000	1.031	1.063	1.096	1.130	1.165	2005
FROM 2006									1.000	1.031	1.063	1.096	1.130	2006
FROM 2007										1.000	1.031	1.063	1.096	2007
FROM 2008											1.000	1.031	1.063	2008
FROM 2009												1.000	1.031	2009
FROM 2010													1.000	2010



N. Spreading Model (Based on Beta Curve)

The beta curve, also known as the normal distribution curve, was developed at JSC in the 1960s. It is used for spreading parametrically derived cost estimates and for R & D type contracts whereby costs build up slowly during the initial phases, and then escalate as the midpoint of the contract approaches.

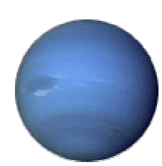
A beta curve is a combination of percent spent against percent time elapsed between two points in time. For example, if an analyst was interested in estimating the software for a satellite program, a rule of thumb is to use a beta curve 60/40 (60% of the funds spent in the first half of the project and the other 40% in the second half) for space cost spread and 40/60 (40% of the funds spent in the first half of the project and the other 60% in the second half) for ground cost spread between two designated dates (e.g., January 1, 2002 to December 31, 2006). Please see the Exhibit N-1 below.

BETA CURVE COST SPREAD FACTORS

Spread Factor Categories
(First Half; Second Half)
50:50
60:40 *for 40:60 or 30:70, use percents in reverse sequence*
70:30

		Annual Factor (Percent) By Year									
OGIVE	**Years**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
50:50	**1**	100									
	2	50	50								
	3	21	58	21							
	4	10	40	40	10						
	5	6	26	36	26	6					
	6	4	17	29	29	17	4				
	7	3	12	22	26	22	12	3			
	8	2	9	17	22	22	17	9	2		
	9	1	7	13	19	20	19	13	7	1	
	10	1	5	11	15	18	18	15	11	5	1
60:40	**1**	100									
	2	60	40								
	3	31	53	16							
	4	19	41	32	8						
	5	12	31	33	20	4					
	6	9	23	28	24	13	3				
	7	6	17	24	24	18	9	2			
	8	5	14	20	22	19	13	6	1		
	9	4	11	16	19	19	15	10	5	1	
	10	3	9	14	17	17	16	12	8	3	1
70:30	**1**	100									
	2	70	30								
	3	45	42	13							
	4	28	42	23	7						
	5	18	38	25	14	5					
	6	12	32	26	17	10	3				
	7	9	26	25	18	12	7	3			
	8	7	21	24	18	13	9	6	2		
	9	5	16	23	18	14	10	7	5	2	
	10	4	13	21	18	14	11	8	6	4	1

Exhibit N-1: Beta Curve Cost Spreading



Another way of spreading costs using the beta curve is to express the cumulative cost fraction as a function of the cumulative time fraction, T:

$$\text{Cum Cost Fraction} = 10T^2(1 - T)^2(A + BT) + T^4(5 - 4T) \text{ for } 0 \le T \le 1$$

Where:

- A and B are parameters (with $0 \le A + B \le 1$)
- T is fraction of time
- A=1, B= 0 gives 81% expended at 50% time
- A=0, B= 1 gives 50% expended at 50% time
- A=0, B= 0 gives 19% expended at 50% time

This formula and methodology was extracted from the NASA Systems Engineering Handbook (http://ldcm.gsfc.nasa.gov/library/NASA%20Syst%20Eng%20Handbook.pdf).

Finally, a simple online cost spreading calculator is located at http://www.jsc.nasa.gov/bu2/beta.html. This online tool can be used to spread the estimated cost of a program up to 8 years. The calculator uses a beta curve to determine the amount of money to be spent in each year based on the fraction of the total time that has elapsed.

O. NASA Cost Estimating and Analysis Lessons Learned

By Andy Prince

1. Everyone is an expert on cost. Get used to it.

2. Understand your customer's requirements. We provide a service to the Agency and that service must always in consonance with the customer's needs.

3. The cost breakdown structure (also called the work breakdown structure) is the foundation of the estimate. Put it together carefully to ensure that nothing is left out and that nothing is double counted.

4. Carefully document all of your ground rules and assumptions. These are the heart and soul of the estimate. Many cost estimates have been misunderstood and misused because the ground rules and assumptions were not explicit.

5. A cost estimate is by definition a subjective analysis. Seek as much independent input and review as time and circumstances allow in order to counteract your particular biases.

6. The design engineers are your friends. Work closely with them to understand the complexities of their subsystem, as well as the uncertainties. If you have not met with every lead designer on a project and captured their knowledge and understanding into the estimate, your results are no better than a ballpark guess.

7. Use all cost models with an ounce of skepticism. They are guides based on past experience and are at best a fuzzy predictor of the future.

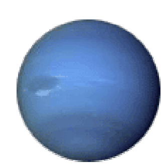
8. The only thing that can be said with certainty about a cost estimate is that the final cost will be different. The real question is not how right you are but how wrong you are.

9. Make sure your work is logical and defendable. If you cannot explain how you arrived at your results based on the evidence in hand, past experience, and expert judgment you will not be taken seriously.

10. Presentations should be clear and concise. Provide sufficient information to ensure that people understand how you arrived at your results, but don't get bogged down in detail (put that in the backup charts for the occasional person who wants a core drill).

11. Be careful with statistics and statistical analyses. NASA management often does not have the background to understand statistics and how they are used.

12. Every estimator gets bloodied now and then. Don't take it personally and don't be defensive. Listen carefully for the message behind the attack, there may be something that you need to hear and act upon.



13. I use what I call the "half rule" to tell if my cost estimates are reasonably accurate. The "half rule" says that if half the people in the audience think your estimate is too high, and half the people think your estimate is too low, you are probably about right.

14. All cost estimates should be evaluated with a sensitivity analysis. The sensitivity analysis will tell you what is and is not important to the results, and can sometimes produce interesting surprises.

15. A cost estimate is just that, an estimate. Perform a probabilistic risk assessment to understand the level of uncertainty in the estimate as well as defining a range of probable outcomes.

16. A good cost estimate cannot overcome bad management. A cost estimate is just another piece of information that goes into the management puzzle. You cannot (and you should not) dictate how management chooses to use that information.

17. You will often get pressure to produce a specific result. Be aware of that pressure and responsive to it, but don't let it override what the data and your knowledge and experience tell you.

18. Consistency before truth. If you have not established a consistent, logical process to achieving the estimate, then you can neither explain your results nor do you have a basis for improvement.

19. The first test of any estimate is credibility. Credibility can only be established with the help of others. Independence is determined by who provides the assessment of credibility.

20. Producing a good cost estimate is an iterative process. Anyone who thinks that they can get it right the first time is naïve.

21. This profession is not for sissies and wimps. Integrity and courage are required to stand up for your work.

22. Question everything. Question the inputs, the models, the assumptions, and the logic of the estimate. Question everything in the search for truth. But, be careful that the questioning doesn't turn into an inquisition; you will loose credibility with your customer.

P. Customer Feedback Form

SYSTEMS MANAGEMENT OFFICE

ENGINEERING COST/RESOURCE ANALYSIS OFFICE

CUSTOMER SURVEY

Project: ____________________ Date: ____________

The Systems Management Office is always looking for ways to improve the quality of its services. Please take a few minutes to answer the following questions. Your comments and suggestions will be used to improve processes and our ability to respond to your future requests for services.

		Never 1	2	3	4	Always 5
1.	Did we effectively communicate with the project team to gain a good understanding of the project?					
2.	Were any data collection forms and related preparation instructions clear and understandable?					
3.	Was our final product clear and documented at the level of detail that you required?					
4.	Did we provide appropriate supporting information to facilitate your understanding of the analysis, scope, and the methodology used?					
5.	Were all your concerns/questions answered in a timely manner?					

6. Please provide us your ideas or suggestions which may help us develop better methods that you think will improve the quality of our response.

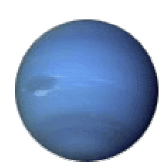
7. Is there a service that we currently do not provide that you would find helpful? If yes, please describe and be as specific as possible.

		Poor 1	2	3	4	Excellent 5
8.	How would you rate the overall service provided?					

Thank you for your comments and suggestions.

Please return this form to: AE3/Manager, Engineering Cost/Resource Analysis Office

The Customer Feedback Form was developed by Robert Sefcik at GRC.



Q. Major Requirements of Federal Law

Exhibit Q-1: Federal Guidelines Provide the Framework for Making Sound Information Technology Investments

Federal Law/ Regulation/ Policy	Summary of Major Requirements
Clinger-Cohen Act (Information Technology Management Reform Acquisition [ITMRA])	• Ensure that IT investments support core mission functions • Establish a Capital Planning and Investment Control Process that links mission needs, information, and information technology in an efficient and effective manner • Demonstrate the criteria used to select and manage the IT investment portfolio • Institute performance measures and management processes that monitor actual performance against expected results • Achieve at least a 5% decrease in cost incurred for operating and maintaining information technology during the 5-year period beginning 1996; achieve a 5% increase in operational efficiency through improvements in IT resource management beginning 1996 • Conduct post-implementation reviews of information systems and information resource management processes • Ensure that variations greater than 10% in cost, schedule and performance are reported to Congress
OMB Circular A-11	• Ensure that the Capital Plan is operational and supports the Information Resource Management (IRM) Strategic Plan
OMB Circular A-94	• Provide evidence of a projected return on investment in the form of reduced cost; increased quality, speed, or flexibility; and improved customer and employee satisfaction • Prepare a cost/benefit analysis for each information system throughout the life cycle that describes the... ○ Level of investment ○ Performance measures ○ A consistent methodology with regard to discount rates for cost benefit analyses of federal programs

Federal Law/ Regulation/ Policy	Summary of Major Requirements
OMB Circular A-130	• Ensure that IT investments support core mission functions • Ensure that improvements on existing IT investments do not unnecessarily duplicate capabilities within the same agency, from other agencies or from the private sector • Provide a strategy that identifies and mitigates the risk associated with the development and operations of IT systems
Government Performance Results Act (GPRA) of 1993	• Develop an annual performance plan and an agency strategic plan • Demonstrate a projected return on investment that equals or exceeds alternatives

As the role and importance of information technology has extended to most activities within all Federal Agencies, the government has defined specific guidelines for evaluating IT investments. The guidelines were established to ensure that agencies make IT investments that improve organizational performance and support sound fiscal management. The following four Acts guidelines are the most relevant to the investment in TIMS.

Clinger/Cohen Act
(or the Information Technology Management Reform Act)

The Clinger/Cohen Act, or Information Technology Management Reform Act (ITMRA), of 1995 directs the Office of Management and Budget to establish clear and concise direction regarding investments in major information systems, and to enforce that direction through the budget process. The spirit and intent of ITMRA directs agencies to ensure that IT investments are improving mission performance through the following actions:

- Establish goals for improving the efficiency and effectiveness of agency operations and, as appropriate, the delivery of services to the public through the effective use of information technology.
- Ensure that performance measurements are to measure how well the information technology supports programs of the executive agency.
- Where comparable processes and organizations in the public or private sectors exist, quantitatively benchmark such processes in terms of cost, speed, productivity, and quality of outputs and outcomes.
- Analyze the missions of the executive agency and, based on the analysis, revise the executive agency's processes as appropriate before making significant investments in information technology.
- Ensure that the information security policies, procedures, and practices of the executive agency are adequate.

Government Performance and Results Act (GPRA)

The purpose of GPRA is to provide for the establishment of strategic planning and performance measurement in the Federal Government. GPRA, in its most basic form, addresses three main issues; change, obtaining results, and performance measurement.

GPRA changes the way the Federal government does business. GPRA changes the accountability of Federal managers; shifts organizational focus to service quality and customer satisfaction; and improves how information is made available to the public. GPRA states that an organization's mission should drive its activities. GPRA further states that the final measure of Federal program effectiveness and efficiency is results, and it requires organizations to measure the results through stated goals and results.

OMB Circular No. A - 94 Guidance on Executive Order No. 128

Circular A-94 provides an analytical framework for capital planning and investment control for information technology investments. The circular provides the information necessary to complete a thorough review of an IT investment's financial performance.

OMB Memorandum from Franklin D. Raines dated October 25, 1996 (the "Raines Rules")

This memorandum, issued by the Director of OMB, addresses the three previous documents and summarizes the goals that agencies should strive to achieve when making IT investments. The eight items outlined by Mr. Raines set the criteria for making IT investments that meet the goals of ITMRA, GPRA, and other Federal legislation. The memo states that most effective long-term investment strategy is guided by a multiyear plan. The plan is a roadmap for getting from "where we are today" to "where we want to be"—achieving the strategic mission goals of the organization in the framework of the Government Performance and Results Act (GPRA). Specifically, it provides eight criteria that can help guide organizations in making sound IT investments. The criteria are classified into three general topics; policy, planning, and risk management. The first four decision criteria relate specifically to capital planning. The fifth criterion establishes the critical link between planning and implementation—information architecture—that aligns technology with mission goals. The last three criteria establish risk management principles to ensure a high level of confidence that the proposed investment will succeed.

R. Trade Study Preparation Guide

I. REPORT OUTLINE

1.0 PURPOSE
A brief but clear statement of reasons for doing the study.

2.0 STATEMENT OF THE PROBLEM
This section should contain a statement of the specific trade-off being performed, a list of the assumptions and initial conditions, a reference to the mission need, and applicable NASA requirements and constraints.

3.0 DESCRIPTION OF THE SELECTION SCHEME AND CRITERIA USED
This may be a reference to another report describing a computer program model or may be a detailed description of the scheme, depending on the study. It should discuss costs or economic factors, the parameters used in the selection process, any weighting factors used, and the rationale for their selection.

4.0 IDENTIFICATION OF DESIGN APPROACHES/CHARACTERISTICS
This section should contain word descriptions, schematics, drawings, component lists, development timelines, mass statements, etc. for each of the candidates.

5.0 COARSE SCREENING
In this section, the number of candidate solutions is reduced (if necessary) by eliminating those candidates unacceptable for delta cost, risk, safety, performance, schedule, or other reasons.

6.0 SELECTION OF PREFERRED APPROACH
This section should include, as applicable, reliability analysis, hazard analysis, maintainability, downtime analysis, trajectory analysis, cost / economic analysis, environmental analysis, etc. All analysis data should be included which is required to make the decision. This section should describe the calculations and data to compute the figure of merit as well as any qualitative data used in the selection to evaluate risk and the relative benefits of the candidates. If any sensitivity testing of results is performed in the selection process, it shall also be described.

7.0 RECOMMENDATION

II. DISCUSSION

A. <u>Section 2.0, "Statement of the Problem"</u>
Once a trade study action has been identified as necessary, the problem should be stated explicitly and the conditions of the study should be clearly defined. The mission requirements/constraints should be referenced and briefly summarized. The assumptions, ground rules, and initial conditions should be defined and agreed upon by the responsible engineer, other participants, and where judged necessary, by NASA. For example, if the tradeoff is dependent on an interface or condition that has not been defined and one must be assumed, this assumption must be a requirement to all. The impact of costs on the conduct of the study and on other program elements and trade studies should be defined.

B. <u>Section 3.0, "Description of the Selection Scheme and Criteria Used"</u>
This section of the trade study report should describe the criteria that will be used to select the best of the alternatives considered. Alternatives that do not meet requirements should be eliminated in the coarse screening process. The criteria then apply to the remaining alternatives. Cost must be considered in all trade studies. For some studies, delta life cycle cost may be the selection criteria. For other studies, the selection criteria may consist of a combination of parameters utilizing a weighting scheme to arrive at a selection. In this situation, a means must be described for quantitatively summing factors having different dimensions, such as weight, power usage, reliability, life cycle costs, safety, schedule, risk, etc.

Where a combination of parameters must be used to make a selection, the following steps are necessary:

1. Select the parameters. Care should be taken to select the most meaningful parameters, only use those which judgment or preliminary analysis indicates a significant difference exists for the candidates. Always include life cycle cost as a parameter or explain why it is not a discriminator.
2. Assign relative value to the parameters. For example, parameter A-45%, parameter B-25%, parameter C-15%, parameter D-10%, parameter E-5%.
3. Based on the values of the parameters, convert them to a common dimensionless number. A range of 0 to 10 works adequately.
4. Using the converted dimensionless number and the assigned weighting factors, the alternative that best meets the selection criteria can be established.
5. A sensitivity analysis must then be performed to see if the conclusion holds true over a reasonable range for the assumptions involved.

C. Section 4.0, "Identification of Design Approaches"

Configuring the candidate solutions consists of establishing a conceptual and/or configuration description of each of the alternative or candidate designs. Only reasonable attainable design approaches shall be pursued considering technical capabilities, delta cost, return on investment, schedules, system safety, system effectiveness, resource limitations, or other constraints as specified in system requirement documentation. The detail or depth of this definition will depend on the level at which the trade study is being made, i.e., system level, subsystem, component, etc. In general, the description will be in terms of block diagrams, schematics, word descriptions, drawings, functional characteristics, etc. Level of detail should be kept consistent. For example, it serves no purpose to describe the detail schematic of one function when all of the others are known only to the input-output level. Characteristics of each candidate shall relate and be restricted to those attributes of the design approach that bear most directly on its feasibility in relation to the requirements. Sufficient information should be included to identify the relationship of system elements under consideration with respect to their interfaces. Impact on other system elements may have a significant benefit or delta cost which will influence the system value of the candidate.

Description of the candidates should be complete enough to convey an understanding of the designs and permit evaluation required by the selection criteria.

D. Section 5.0 "Coarse Screening"

If the scope of the trade-off is to pick the recommended approach or concept from a large number of possible solutions, it is usually impractical to perform a detail evaluation on a large number of candidates because of the limitations of time and money. It is necessary to reduce the number of candidates by one or more steps which "filter out" less attractive solutions. These coarse filters require simple criteria that permit a quick assessment of each candidate’s value. Comparisons may be presented in the form of a simple matrix. The objective is to identify:

1. High risk
2. Questionable technical feasibility
3. A likely uncompetitive cost or schedule impact
4. Incompatibility with program objectives

E. Section 6.0, "Selection of Preferred Approach"

The selection process consists of performing analyses to evaluate the capability of each candidate concept to satisfy selected criteria and comparing the results. Selection of the approach frequently involves support of other specialists, such as weight analysis, reliability analysis, maintainability, human engineering, system safety, and logistics. The specialist must be brought into the trade study exercise, as required, and their analysis incorporated into the study. Selection must include:

1. Measurement of system effectiveness of the candidates
2. Arriving at delta economic impacts between candidates
3. Assessment of relative risk.

Examples of possible evaluation data are presented in Table I. The form of the evaluation data will vary depending on the nature of the study. Where a discrete number of alternatives are being considered, the data may be a comparison of the candidates' capability with respect to a requirement or constraint. In cases where a large number of candidates are being considered, the evaluation data may be in the form of parametric relationship.

The selection of the preferred approach is made by applying the evaluation data to each candidate to identify the candidate having the greatest benefit to the program.

The objective in this element of the study is to obtain a single figure of merit of the worth of each candidate and to select the one having the greatest relative value. The basic data used in the selection method should always be presented in the study in an arrangement that shows a comparison of the candidates. A final decision will require an understanding of the basic data used in the selection mode. If there are qualitative considerations which have not been directly included, these factors should also be shown in a comparison matrix. Because of the probabilistic nature of much data, the quantitative measurement of candidate value is not absolute and the selection process will not necessarily reveal a clear and distinct best approach. For this reason, it will often be necessary to perform a sensitivity analysis by varying the data over the range of their uncertainty to determine if the selection is affected.

Reasons to substantiate the selection made shall be provided. These may be in the form of schematic diagrams, outline drawings, interface details, functional diagrams, reliability data, statistical analyses, and narrative and any other backup data necessary to support the selection. The reasons shall cover the requirements that the selected approach impose on other segments of the system. The requirements imposed on facilities, training, training equipment, human performance, and procedural data shall be determined and documented.

TABLE I. - EXAMPLES OF EVALUATION DATA

ECONOMIC COMPARISONS	SYSTEM PARAMETERS	
Life Cycle Cost	Weight	Procurability
DDT&E Cost	Volume	Producibility
Acquisition Cost	Design Life	Transportability
Operations and Support and All Sub-Elements per Program Ground Rules	Accuracy	Logistics
Disposal Cost	Sensitivity	IMLEO
Economic Measures	Reliability	TRL
Net Present Value	System Safety	EMP/EMI Susceptibility
Return on Investment	Security	Growth Potential
	Maintainability	Power Consumption
	Range	
RISK ASSESSMENT		
Identification		
Types:		
Cost		
Schedule		
State-of-the-Art		
Critical Failure (Technical or Technology Maturity)		
Margins of Safety		
Programmatic		
Quantification		
Controllability		
Monitor		

ATTACHMENT – QUALITATIVE RISK ASSESSMENT GUIDELINES

1. Risk is determined by the probability that a problem or undesirable situation will occur and by the program impact if it does occur. These two factors can be combined as shown in the following chart to obtain an overall risk assessment.

Program Impact	L	L	M	L	M	H	M	H	H
Probability of Occurrence	L	M	L	H	M	L	H	M	H
Risk	Low			Medium			High		

Alternate Required	
Unacceptable Risk	

2. Program Impact Factors

Factors to consider in categorizing program impact are:

Program Impacts (Risk Assessment)

When Problem Becomes Evident	
During Development	Low
During Flight Test	Medium
During Operational Deployment	High
Effort Required to Eliminate Problem	
Extended Effort	High
Moderate Effort	Medium
Little Effort	Low

These two factors (when the problem becomes evident and effort required to eliminate the problem if it occurs) can be combined using the following chart to categorize program impact:

Program Impact Combination Matrix:

When Problem Becomes Evident	L	L	M	L	M	H	M	H	H
Effort Required to Eliminate Problem	L	M	L	H	M	L	H	M	H
Program Low	Low			Medium			High		

Alternate Required	(grey)
Unacceptable Risk	

3. Probability of Occurrence

The following chart is a guide to estimate the probability of occurrence:

Complexity Leading to Unknowns	High
New or Modified Equipment with Sound Technical Base High Experience Level Adequate Design Margins Reduction of Unknowns Achievable	Medium
Good Knowledge of Environment Technical Within State-of-the Art High Experience Level	Low

4. Risk Assessment - Controllability

Controllability of risk shall be a factor in overall risk assessment. Where the risk is categorized as low (using the techniques described above) it can be assumed that "business as usual" activities will result in effective risk control. Where medium or high-risk categories are strong candidates, necessary future risk control actions need to be considered in the trade study.

ISPA/SCEA International Conference, June 2001 Keynote Speech

MR. MALCOLM PETERSON, COMPTROLLER

NASA

Good morning, ladies and gentlemen.

Thank you for inviting me today to address SCEA and ISPA.

I am pleased to be here. There are a lot of diverse interests represented here including government agencies, industry, universities, and a multitude of organizations on an international scale.

SCEA and ISPA serve a tremendously useful function, not only on occasions like these where there can be an interchange of ideas and perspectives, but also in providing educational opportunities in cost estimating and analysis, establishing standards, and recognizing achievements of its members.

The conference theme—"Parametrics & Cost Analysis: Leading Decision Making for the 21st Century"—hits hard at the roles and responsibilities of each one of us. I'm not sure if "Leading" is quite the word I would have selected. "Facilitating" decision making would be my choice. The problem with "leading" is the directional implication: leading in what direction?

The NASA Administrator, Dan Goldin, has occasionally remarked that he isn't interested in cost estimates based on looking out the back of the bus. Estimates based on "business as usual" don't interest him. He would like to see estimates based on the "best that can be done." His concern is that the cost estimating relationships are drawn upon a potpourri of past performance experience, ranging from developments competently executed, heroically done, to simply incompetent and perhaps unfortunate.

What is his fear? That program leaders will receive inputs from cost estimators that will lead the decision-maker on a conservative path, dissuading them from pushing forward with an aggressive agenda. He has a point. NASA's experience is replete with examples of developments done for far less than we anticipated at the outset.

Of course, there is the other side of our experience, with aggressive initial cost estimates predicated on the information given to us: usually accompanied by the assertion that "this time, we were going to do business in a new way." And, the difficult and often personally challenging dilemma the cost estimator faces is that he or she knows that arguing against that assertion has to be done with extreme care, lest one be seen as "looking out the back of the bus."

I have my own perspective on cost estimating. Here are a few of my thoughts on the art and science of cost estimating. First, and this is not a particularly profound thought, I believe that our ability to estimate is based on knowledge of what has been done before. We have to look out the back of the bus, understand what has been done before and what it cost and why it cost what it did. We have to know the underlying conditions that influenced the final cost.

Was the contractor given a clear set of requirements? Did the availability of timely funding impact the contractor's workplan? Did the contractor use major league ballplayers to execute the program, or was the program used to train the relatively inexperienced, the minor league ballplayers? And, why was that the case? Was the fee so low that the contractor's management applied the major league players somewhere else? Or, did they "buy in" to gain a toehold on a new market opportunity, and thereby cause a series of dysfunctional events to occur, with engineering talent being used to negotiate changes. There are many "why's" and the experienced estimator must recognize and incorporate those into his base of knowledge.

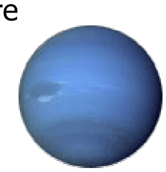
Second, cost estimates are often really quite accurate on the direct costs of labor, purchased parts, and material. And then we apply standard factors, "wraps," to build up the estimate to its final total. Unfortunately, the "wraps" tend to be nearly half the total cost. So, we strain after precision on the direct costs, and use factors on the remainder. We get really good hardware costs, and as good as the art allows on software, and god help us when it comes to hardware/software integration.

Third, we have real problems when it comes to developments that are fundamentally different than our experience base. I remember when one of my staff, Werner Gruhl, was part of a team generating a cost estimate for the National AeroSpace Plane. (You may recall this was the plane that President Reagan dubbed the civilian counterpart as the "Orient Express," because it would fly hypersonically to Tokyo from the U.S. in a matter of hours.) The program advocates thought it would cost perhaps $3-5 billion. Werner and his collaborators told management that it was far more likely to cost several multiples of that, if indeed the NASP could ever meet its technical objectives. When questioned why they were so obviously out of touch with what the technical community thought it would cost, their answer was that the number of technical breakthroughs required was extraordinary and the integrating effects of all those leaps was bound to lead to a lengthy and costly design and engineering development phase.

In this regard, I want to pass on an anecdote. Over a decade ago, in the Presidency of the first George Bush, NASA started on the definition of what was called the Space Exploration Initiative. Eventually, this program was to enable sustained human and robotic exploration of Mars. Typically, the OMB and Congress wanted to know what it would cost over the life cycle before funds would be appropriated for more than the most humble beginning. So, perhaps overly stung by the infamous initial estimate for the Space Station, we decided to generate a 30-year program estimate that was conservative and covered all the bases: robotic vehicles, human transports, cargo ships, a new transportation system, tracking and communications, etc . Our final product was a number that was on the order of $400 billion. And, as you can surmise, we hadn't done much in the manner of design definition and technology development to reduce the number of estimating uncertainties that had to be covered by reserve, so the reserve was high.

And, the politicians deemed the cost "unaffordable." And, the point of the story, a Congresswoman went to the floor of the House and said she didn't believe Congress should appropriate any funds for the design and definition work until NASA could tell her exactly what it would cost.

Those of you who are experienced in this field know all too well that the most important factor in gaining acceptance of the appropriation request to undertake a new and challenging program is whether the estimated cost is regarded as "affordable." And, if the program isn't allowed the time to do the preliminary design and development, build test articles, and learn what works and doesn't before it has to generate that estimate, the error bar is going to be large. And, then the judgment of our leadership on how to deal with the politics of "affordability" is going to be crucial. Getting stuck with a marketing brochure that says what grand things will be accomplished and an "affordable" estimate that doesn't match is a recipe for endless hours of finding "new ways of



doing business." You all recall the cartoon of the engineers at the blackboard with endless calculations and a final number. The caption says, "then a miracle occurred."

My fourth observation: For the most part, over-reliance on the judgment of engineers and scientists, and allowing their "expertise" to overcome your intuitive response to what a program cost estimate should be is poor practice.

Many engineers and scientists are remarkably lacking in humility. Their judgment is often based on what it would take them to design and build something, not the college freshout who is really going to have to do the work. Your intuition, appropriately trained and tempered by appreciation of what things have cost in the past and why they have cost that much, is a truly extraordinary tool. Trust it. You can always find ways of explaining to managers after you have reached your conclusion how you generated the estimate using all sorts of very reliable cost estimating relationships or PRICE or another cost modeling tool.

Before I get off the stage, I would like to point out some specific challenges in the cost analysis arena for NASA.

First, we are seeing a merging and "morphing" of transportation technologies that transverse both aeronautics and space technologies. The Space Shuttle began this trend many years ago. The next generations of advanced space launch and space maneuvering vehicles are going to be an even closer coupling, particularly in the attempt to minimize ground lift off weight by using available oxygen in the atmosphere. The intelligence in these vehicles will have to be extraordinary to make that approach relatively efficient. We will have to understand how to couple our estimating efforts with the engineering design tools to ensure reliable and economical access to space.

Second, we will be pushing the limits on materials and structures for reusable launch vehicles and new spacecraft with very large optics. Future airframes and engines will rely on emerging technology that builds the system from the molecular, or nano-scale – known as nano-technology. This may truly provide the "unobtainium" we need, because the technologists believe they can construct structures made from carbon molecules that can be 100-times stronger than steel, and only one-sixth the weight. Our future materials will be also be "intelligent," with embedded sensors and actuators.

Some of you may have seen the animation of a potential far future aircraft that will morph its wings to cope with the different flight regimes, from low speed to high speed. With flexible membranes as wing skins, embedded sensors, like the "nerves" of a bird, will measure the pressure over the entire surface of the wing and direct the response of the actuators – the "muscles." The wing will adapt to different flight regimes by re-forming to optimal shapes.

This will be coupled with biological computing schemes in the never ending quest to get the computational power that is stored in your brain. This is exciting stuff. Of course, there are those people who want to know what it could cost, so they know whether the investment in the technologies should be made. They don't want to allocate their scarce resources to these technologies unless there is a real likelihood of a breakthrough in reducing transportation costs. So, how do you estimate this "exciting stuff"?

Quite frankly, I don't get a warm and fuzzy feeling when my estimators give me an estimate for "proof-of-concept" efforts.

There lies the estimating challenge.

I am skeptical that the proven tools in your arsenal of estimating methodologies will be capable of rendering reliable estimates. Yes, of course, you're working on the refinement of those tools, particularly software-estimating tools. But, your data is going to have to be rapidly refreshed if you are to keep up with the pace of technical change. Not just a retrospective look at the costs of a completed development program, but extraction of current data, complete with the necessary understanding of the "why's."

Question: if we've been operating on dollar per pound, I will ask you now--what is "dollar per nano" or what is a "dollar per bio"?

Finally, the cost estimators in industry and NASA are increasingly going to be operating as collaborators in an engineering design environment that calls for quick reactions to design options in the search for an optimum design matching mission effectiveness and cost effectiveness. I am told by those who work in the technology that we will have intuitive, high-confidence, highly networked engineering design environments will allow us to design from atoms to aerospace vehicles, with higher quality in much shorter time spans. Cost modeling is going to be challenged to be a partner in this design process.

A new generation of scientists, engineers, and professionals will be tasked to unleash the incredible range of innovation and opportunity that is possible in future aerospace systems. They are going to have to understand the what and why of the cost of their designs. They will have to speak our language so that the time to communicate is short enough to enable a true collaboration.

I do have a real concern about NASA's readiness to meet this challenge. I know there will not be enough cost experts within the government to carry on in the pursuit of cost estimating and analysis. We will have to engage the talents resident in non-governmental entities to ensure reliable cost estimates are provided to management. But, we will have to be highly competent inside NASA as well.

To address this concern, I have instituted the NASA Cost Analysis Steering Group, chaired by Rey Carpio, to implement initiatives and recommendations to improve cost estimating and analyses.

We are engaging every NASA center to implement the improvement plan.

Will the funding be there to turn proposals into reality? I think so. I know what is all to likely to occur if we fail to provide the resources needed to make the needed investments in new tools, fund the training, and procure the complementary cost estimating capabilities.

And as I survey this audience, with some of the best NASA cost analysts among you, I trust that you will find the upcoming sessions a valuable learning experience and come away from here ready for the challenges ahead.

Ladies and Gentlemen, let's get to work.

Thank you very much.

NASA

COST ESTIMATING HANDBOOK

NASA Purchase Order: L-14919

Contract Number: GS-23F-9755H

Task Number: 19815-0010/0025

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